OFFICE OF THE PARLIAMENTARY BUDGET OFFICER

BUREAU DU DIRECTEUR PARLEMENTAIRE DU BUDGET

Feasibility of Budget for Acquisition of Two Joint Support Ships

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The mandate of the Parliamentary Budget Officer (PBO) is to provide independent analysis to Parliament on the state of the nation's finances, the government's estimates and trends in the Canadian economy and, upon request from a committee or parliamentarian, to estimate the financial cost of any proposal for matters over which Parliament has jurisdiction.

The PBO received requests from the Member from St John's East and the Member from Scarborough-Guildwood to undertake an independent cost assessment of the Joint Support Ship (JSS) project. This report assesses the feasibility of replacing Canada's current Auxiliary Oiler Replenishment ships with two JSSs within the allocated funding envelope.

The cost estimates and observations presented in this report represent a preliminary set of data for discussion and may change subject to the provision of detailed financial and non-financial data to the PBO by the Department of National Defence, Public Works and Government Services Canada, and the shipyards. The cost estimates included reflect a point-in-time set of observations based on limited and high level data obtained from a variety of sources. These high-level cost estimates and observations are neither to be viewed as conclusions in relation to the policy merits of the legislation nor as a view to future costs.

The authors would like to thank the members of the independent Peer Review Panel for their comments and guidance. Any errors or omissions are that of the authors.

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List of Acronyms

ACAN	Advanced Contract Award Notice
AOR	Auxiliary Oiler Replenishment Ship
BY	Base Year
CER	Cost Estimating Relationship
CFDS	Canada First Defence Strategy
CY$	Constant-Year Dollars
DDA	Design Development Activities
GAO	U.S. Government Accountability Office
ICE	Independent Cost Estimate
JSS	Joint Support Ship
MCPLXS	Manufacturing Complexity for Structure
NSPS	National Ship Procurement Strategy
O&S	Operations and Support
PBO	Parliamentary Budget Officer
RFP	Request for Proposals
ROM	Rough Order of Magnitude
SE/PM	Systems Engineering/Program Management
SME	Subject Matter Expert
SOR	Statement of Requirements
TY$	Then-Year Dollars
WBS	Work Breakdown Structure

1 Executive Summary

1.1 Précis

In 2004, the Government of Canada announced that it would replace the Royal Canadian Navy's Protecteur-class Auxiliary Oiler Replenishment (AOR) ships. Three Joint Support Ships (JSS) were proposed, with a contract to be awarded in 2008, the first ship delivered in 2012, and the project completed in 2016.[1] The Government allocated $2.1 billion to design, develop, and acquire the three ships.[2]

In 2009, however, the Government found that the three ships would not fit within the $2.1 billion budget. In response, the number of ships was reduced to two, delivery dates pushed out, and requirements changed. [3]

The new budget was set at $2.60 billion in fixed nominal dollars.[4] This means that the Government plans to make $2.60 billion available to design and build the ship, with no further adjustments for inflation.

Members for St John's East and Scarborough-Guildwood requested the PBO assess the sufficiency of the JSS's $2.60 billion budget. The PBO developed a parametric cost model for this purpose. As the final characteristics of the JSS are not entirely clear, the PBO estimated the cost of replacing the current Protecteur AORs with two analogous ships built according to Government procurement rules in Canada. All figures in this report are presented in nominal fixed dollars.

Table 1-1: Comparison of DND and PBO Estimates and Budgets for Protecteur Replacement

	DND	PBO
Estimate	$2.53 billion	$3.28 billion
Budget	$2.60 billion	$4.13 billion

Sources: National Defence and Canadian Forces, *supra* note 4; DND estimate from "JSS Historical Options Analysis Costing Brief to PBO" June 12, 2012.[5]

As shown in Table 1-1 above, DND estimates that replacing the Protecteur will cost about $2.53 billion, and the budget set aside is about $2.60 billion. The PBO's model suggests that these amounts will be insufficient. It estimates that replacing the Protecteur will cost about $3.28 billion, but that, given the stage of the program and uncertainty surrounding its characteristics, U.S. Government Accountability Office (GAO) best practice recommends budgeting no less than $4.13 billion.

Replace Protecteur: PBO results are based on replacing the Protecteur, which is understood to satisfy DND's minimal requirements of logistics support at sea.

All acquisition costs: The results include all acquisition costs, consistent with Treasury Board practice requiring inclusion of all overhead—DND employee salaries, pensions and benefits, and taxes.

Build in Canada: The results are based on the National Shipbuilding Procurement Strategy (NSPS)'s "Build in Canada" condition and Canadian labor rates.

[1] Treasury Board of Canada Secretariat, *2008-2009 Reports on Plans and Priorities: National Defence*, (2008), online: Treasury Board of Canada Secretariat <http://www.tbs-sct.gc.ca/rpp/2008-2009/inst/dnd/dnd-eng.pdf>.

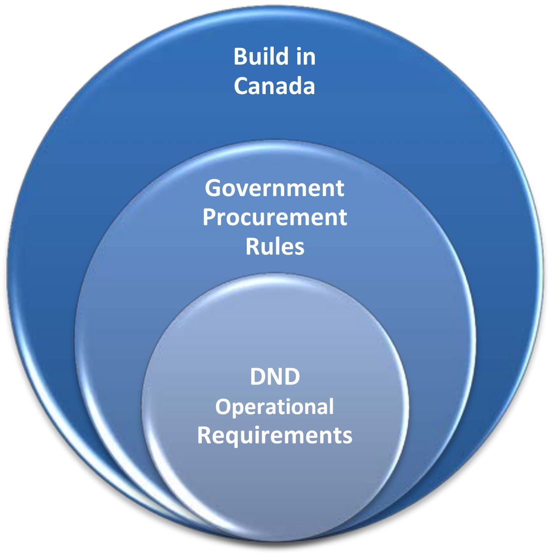
[2] Sarah Gilmour, *Domestic Stories: JSS and Amphibious Ships Working Together: the Navy Plans for Future Additions* (23 November 2005), online: Royal Canadian Navy <http://www.navy.forces.gc.ca/cms/3/3-a_eng.asp?category=7&id=481>.

[3] National Defence and the Canadian Forces, *Internal Audit of Joint Support Ship (JSS) Project* (November 2011), online: National Defence and the Canadian Forces <http://www.crs-csex.forces.gc.ca/reports-rapports/2011/176P0934-eng.aspx#bg>.

[4] National Defence and the Canadian Forces, New Releases, NR-10.074, "Government of Canada to Acquire New Joint Support Ships" (14 July 2010) online: National Defence and the Canadian Forces <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?cat=00&id=3463>. While a budget of $2.33 billion is indicated, officials from DND have confirmed that a contingency of $0.30 has been allocated as well, bringing the total budget to $2.63 billion.

[5] DND briefing provided two estimates: $2.533 billion for new design and $2.518 for Military Off the Shelf. PBO presents average of these. Of note is that these estimates fall below DND's 2008 estimate of $2.96 billion for two Canadian AORs. DND, "Preliminary Cost Analysis for PROTECTEUR Class Replacement," dated 29th Aug 2008. Using DND's escalation rates, this would bring this estimate in line with the PBO's at $3.2 billion.

Figure 1-1: Total Cost



Source: PBO

1.2 Background

In June 2010, the Government announced Canada's National Shipbuilding Procurement Strategy (NSPS).[6] The NSPS aims to create a robust domestic shipbuilding industry to help the Government achieve its objectives for the Navy and Coast Guard outlined in the Canada First Defence Strategy (CFDS).

NSPS is a multi-departmental approach to federal procurement, which seeks to develop a longer-term, strategic relationship between government and industry by selecting two shipyards: one to build the combat work-package and the other to build the non-combat work-package of ships.[7]

In October 2011, the selection was announced, with Seaspan's Vancouver Shipyards winning the non-combat package and Irving Shipbuilding in Halifax the combat package.[8]

In February 2012, the government and shipyards signed umbrella-agreements.[9] By and large, these agreements are not binding on the government or the shipyards. The only exception to this is a provision that outlines how the shipyards are to be compensated should the Government eliminate or reduce its planned procurements.[10]

In due course, separate, binding, individual contracts for each class of ship will be signed.

Once built, the JSS will replace the Navy's current AOR vessels—the Protecteur and the Preserver. These ships have been in operation for more than 40 years and are nearing the end of their service lives.

It is hoped the new JSS will provide core replenishment, underway medical-support to naval task groups, limited sealift capabilities, and limited support to forces ashore.[11]

[6] Public Works and Government Services Canada, *National Shipbuilding Procurement Strategy (NSPS)* (27 July 2011), online: Public Works and Government Services Canada <http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng.html>.

[7] National Defence and the Canadian Forces, *Backgrounder: Canada First Defence Strategy* (12 May 2008), online: National Defence and the Canadian Forces <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?cat=00&id=2645>; Public Works and Government Services Canada, *supra* note 6.

[8] Public Works and Government Services Canada, *Results of the National Shipbuilding Procurement Strategy* (19 October 2011), online: Canada News Centre, <http://news.gc.ca/web/article-eng.do?mthd=tp&crtr.page=1&nid=629989>. These shipyards would be designated as sources of supply for large vessels (1000 tonnes displacement or more): one for combat vessels, including the Canadian Surface Combatant (CSC) and Arctic/Offshore Patrol Ships (AOPS), and one for non-combat vessels, such as the JSS.

[9] Public Works and Government Services Canada, *Canada Signs Long-term Agreements with NSPS Selected Shipyards* (15 February 2012), online: Canada News Centre <http://news.gc.ca/web/article-ng.do?nid=656979>.

[10] Government of Canada, *Umbrella Agreement Between Vancouver Shipyards Co Ltd and Seaspan Marine Corporation and Her Majesty the Queen in right of Canada, as represented by the Minister of Public Works and Government Services* (Ottawa: National Shipbuilding Procurement Strategy, 2012) at s 6.9.

[11] The project has four main deliverables: (1) design of a new class of ship; (2) construction of two ships, with an option for a third; (3) provision of the necessary infrastructure and other logistics support to facilitate the transition of the new ships into service; and (4) in-service support contract to provide maintenance, repair and overhaul, long-term spares, and technical support for the life of the ships. National Defence and the Canadian Forces, *Joint Support Ship (JSS)* (8 August 2011), online: National Defence and the Canadian Forces

1.2.1 JSS Program History

A letter was issued in February 2005 inviting companies to express interest in the project.[12] Four industry teams were pre-qualified to compete.[13] The Government issued a request for proposals (RFP) on July 1, 2006.[14]

The acquisition budget for the project was set at $2.1 billion accompanied by an $800 million service contract allotment.

In the project definition phase, two teams—ThyssenKrupp Marine Systems AG (TKMS) and SNC-Lavalin Profac Inc.—were each awarded a $12.5 million contract to produce and deliver an implementation proposal consisting of a preliminary ship design, a project implementation plan, and an in-service support plan. Those proposals were then evaluated to determine which demonstrated the best value.

In August 2008, the Government terminated the JSS project as both proposals were deemed to be non-compliant with the terms of the RFP. One team submitted a proposal for only two ships while the other's proposal was significantly over budget.[15]

In July 2010, DND issued background materials on a second attempt at the JSS project. In the new iteration, DND pegged the "total investment for the acquisition" at "approximately $2.6 billion", inclusive of taxes.[16]

Understanding Government of Canada budgets
Acquisition budgets must include all costs associated with a procurement, including: salaries, contributions to employee benefits and pensions, project management, contracts, design fees, licensing fees, industrial and regional benefits management, construction, quality assurance, contingency, and all applicable taxes (approx. 13%).

DND started by assessing then existing designs for vessels operating within a NATO Navy and meeting a minimum set of Canadian requirements.

In October 2010, an advanced contract award notice (ACAN)[17] was posted on the MERX procurement board announcing that the government had found only two suitable designs: ThyssenKrupp Marine

<http://www.forces.gc.ca/aete/jointsupportshipjss-projetdunaviredesoutieninterarmeesnsi-eng.asp>; National Defence and the Canadian Forces (12 May 2008), *supra* note 7.

[12] MERX, *Letter of Interest (LOI) Joint Support Ship (JSS) Project* (25 February 2005), online: MERX <http://www.merx.com/English/SUPPLIER_Menu.asp?WCE=Show&TAB=1&PORTAL=MERX&State=7&id=PW-%24%24ML-007-11171&src=osr&FED_ONLY=0&ACTION=PAGE2&rowcount=13&lastpage=2&MoreResults=&PUBSORT=0&CLOSESORT=0&IS_SME=&hcode=yS%2fQ1u%2bzKuWWKi14TbGEXQ%3d%3d>.

[13] MERX, *Project Definition for the Joint Support Ship (JSS)* (28 June 2006), online: MERX <http://www.merx.com/English/SUPPLIER_Menu.asp?WCE=Show&TAB=1&PORTAL=MERX&State=7&id=PW-%24%24MD-007-13671&src=osr&FED_ONLY=0&ACTION=PAGE1&rowcount=13&lastpage=2&MoreResults=&PUBSORT=0&CLOSESORT=0&IS_SME=&hcode=5A%2fMIWQ3g3JPg76I0MYcpg%3d%3d>.

[14] *Ibid.*

[15] Defense Industry Daily, *Canada's C$ 2.9B "Joint Support Ship" Project, Take 2* (13 October 2010) online: Defense Industry Daily <http://www.defenseindustrydaily.com/canada-issues-rfp-for-cdn-29b-joint-support-ship-project-updated-02392/>.

[16] National Defence and the Canadian Forces, New Releases, NR-10.074, "Government of Canada to Acquire New Joint Support Ships" (14 July 2010) online: National Defence and the Canadian Forces <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?cat=00&id=3463>.

[17] An advanced contract award notice is a contracting vehicle used by the Government of Canada to expedite the procurement process typically used when it is believed that only one supplier is capable of meeting the procurement requirements. Notice is posted for no less than 15 calendar days to allow other parties to indicate if they would be able to meet the requirement. In this case, presumably, an ACAN was used to confirm that only two NATO ship designs met the requirements for the JSS. Refer to: Treasury Board of Canada Secretariat, *Guide for Managers - Best Practices for Using Advance Contract Award Notices (ACANS)* (January 2004), online: Treasury Board of Canada Secretariat <http://www.tbs-sct.gc.ca/pubs_pol/dcgpubs/contracting/acan_guide01-eng.asp>.

Systems' Berlin Class and Navantia S.A.'s Cantabria Class. [18]

TKMS was provided with $3.65 million to assess the risk of implementing the changes to make the Berlin meet the SOR. Once TKMS successfully completed this work, it was awarded an additional amount to undertake design development activities (DDA).

While the Cantabria also met the requirements, the Navy was unable to reach an agreement with Navantia.

Concurrently, the Navy contracted with BMT Fleet Technology (BMT)—a wholly owned subsidiary of BMT Group Ltd—to develop a "clean sheet" design. BMT was provided $9.8 million for this. [19,20]

DND will evaluate the two designs and select one prior to signing the design and build contract with Seaspan. [21] Seaspan will then complete the production design and build the ships. [22]

At the time of publication, both TKMS and BMT were nearing completion of their DDA, and thus, no decision had yet been made as to the final design for the JSS.

1.3 Methodology

There are four main approaches to costing: analogy, parametric, build-up, and expert opinion. In cost estimating, the phase of the project and the availability of data drive methodology selection. [23]

Given that the JSS is still in early design phase (meaning that detailed specifications and actual costs are unavailable) and there are no recent, analogous acquisitions, parametric modeling is the most appropriate method for estimating cost. [24]

Parametric modeling involves positing cost relationships for a set of inputs and testing those relationships using historical data.

Developing and validating a parametric model requires a significant investment of time and access to a data set of historical costs. For this reason, the PBO used PRICE Systems' TruePlanning®—a software package used for estimating cost of hardware platforms.

TruePlanning®

TruePlanning® is a proprietary cost estimating tool that has applications in both military and non-military domains. It is backed by extensive military cost estimating expertise. Clients include the US Department of Defense, Sikorsky Aircraft, NASA, BAE Systems, Gulfstream, United Technologies and Boeing. For a full list, see: <http://www.pricesystems.com/success/customer_overview.asp>.

It is among the only parametric software tools available to comprehensively cost military procurement. Joe Wagner, Vice President of the Society of Cost Estimating and Analysis (SCEA), among others, confirmed that TruePlanning® is widely recognized and highly respected around the world as a robust military cost estimating tool.

Publicly available and confidential data were used as inputs for the model. [25] The reasonableness of all

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[18] MERX, *JSS Military Off The Shelf Designs – ACAN* (8 August 2010), online: MERX <http://www.merx.com/English/SUPPLIER_Menu.asp?WCE=Show&TAB=1&PORTAL=MERX&State=7&id=PW-%24JSS-002-20533&src=osr&FED_ONLY=0&ACTION=PAGE1&rowcount=13&lastpage=2&MoreResults=&PUBSORT=0&CLOSESORT=0&IS_SME=&hcode=IuUnwQfOD07ZwV3oZBOgdQ%3d%3d>.

[19] BMT, *BMT Fleet Technology begins design work for Canada's Joint Support Ship* (23 February 2011), online: BMT <http://www.fleetech.com/News/?/1705/0/781>.

[20] BMT, *BMT Fleet Technology Continues Development of the Contract Design Option for Canada's Joint Support Ship* (15 March 2012), online: BMT <http://www.fleetech.com/News/?/1705/0/972>.

[21] MERX, *JSS MILITARY OFF THE SHELF DESIGNS* (25 January 2012), online: MERX <http://www.merx.com/English/SUPPLIER_Menu.asp?WCE=Show&TAB=1&PORTAL=MERX&State=8&id=1069046&src=osr&FED_ONLY=0&PrevStateId=2&ACTION=&rowcount=&lastpage=&MoreResults=&hcode=AiiatAn%2fzsvKKZwFuLvsRg%3d%3d>.

[22] Public Works and Government Services Canada, *Joint Support Ship (JSS) Project* (25 May 2011), online: <http://www.tpsgc-pwgsc.gc.ca/app-acq/stamgp-lamsmp/nsi-jss-eng.html>.

[23] See Appendix B: Costing Methods.

[24] *Ibid*.

[25] Including the SOR, documentation for the Protecteur, and data relating to similar AOR ships that include a range of potential mission solutions.

assumptions was tested by the PBO's Peer Review Panel and a team of subject matter experts (SMEs) at PRICE Systems.

1.4 Cost Drivers

The model has a number of cost drivers. These are discussed in detail in 2.2 Methodology and Appendix D: Model Inputs.

The major cost drivers of the model are weight and technology. In addition to weight and technology, other inputs drive the model, albeit less significantly.[26]

1.4.1 Weight

Weight refers to the ship's displacement. The larger the ship is, the more it is likely to cost to design and build. The PBO adopted the weight of the Protecteur for its point estimate.

1.4.2 Technology

Technology is a measure of how complicated constructing the platform is; for example, a ship is more complex than a car, but less complex than a fighter jet.

Technology is made-up of four key components:

1. Manufacturing complexity for structure
2. Percent of new structure
3. Percent design repeat for structure
4. Engineering complexity

These variables are defined and discussed below.

1.4.2.1 Manufacturing Complexity for Structure

Manufacturing complexity for structure (MCPLXS) reflects the complexity of the technology involved,[27] its producibility (material machining and assembly tolerances, machining difficulty, surface finish, etc.) and yield.[28]

Analysis suggests that MCPLXS values range from 11.81 in the case of nuclear submarines to 4.02 in the case of destroyers and frigates; although, for some state of the art systems, they can be much higher.

The PBO had production cost and specification data for a number of logistics support ships.[29] These data were used as a basis for an MCPLXS assumption for the Protecteur.

First, the data were normalized. Tonnage for each vessel was converted to common units and costs to a common base year (BY).

Second, the costs and tonnage were fed into the model. The model then returned an MCPLXS for each ship.

The range of MCPLXSs for the ships was relatively tight compared to the ranges of MCPLXS for different platforms noted above. The U.S. Henry J. Kaiser class fleet oiler (a relatively simple oiler carrying victuals) had the lowest MCPLXS coming in at 3.39, and the U.K. Wave Knight class tanker had the highest coming in at 4.25. The Protecteur was in the mid to low range, with an MCPLXS of 3.78.

The PBO adopted the MCPLXS of the Protecteur for its point estimate.

See Appendix C: JSS High Level Requirements. Confidential data was obtained by information requests.

[26] See Appendix D: Model Inputs.

[27] Technology represents the impact to all of the component's manufacturing operations including material, labour, process, equipment, etc.

[28] During any manufacturing operation, there will be some components or sub-assemblies which may have to be reworked or scrapped, requiring additional material and labour resources. This is more predominant in prototype than in the production ship. For example, if the yield is 50% in prototype, it means the builder would need to spend twice more on material and labour.

[29] See list of ships in Appendix F: List of Replenishment Vessels.

1.4.2.2 Percent of New Structure

Percent of new structure represents the amount of new structural design effort needed to complete the project. It may be less than 100% where old designs are adapted and reused in the new design.

Reusing Designs

Reusing designs sometimes makes sense, as it can reduce the amount of design work necessary. As such, although each ship type is a unique overall design in terms of size, shape and volume, ships may contain some designs from previous ships.

Reusing designs, however, does not mean that a ship will require no new design effort. In fact, reusing existing design may also require design effort, as old designs are adapted to new requirements.[30]

The team finally selected to design the JSS may reuse some design components from earlier projects. Even where this is so, however, it is likely that redesign will be required to adapt reused designs to Canadian operational requirements and make construction in a Canadian shipyard possible.[31]

The PBO adopted a value of 85% of new structure. This reflects the fact that any existing design will require significant redesign in order to ensure it responds to Canadian requirements and can be built in a Canadian shipyard. This figure was corroborated by examining Work Breakdown Structure (WBS) library and consulting with SMEs, members of PRICE's team and members of the Review Panel.[32]

1.4.2.3 Percent Design Repeat for Structure

Percent of design repeat is determined by the ratio of redundant hardware to unique hardware.

Repeating Design

Assume that a gearbox has ten gears, five of which are identical. The component has a redundant hardware input of 4. Design repeat is 40% (4 of 10 gears are redundant).

The PBO adopted 40% design repeat for structure, reflecting the fact that there will be some, but not complete, symmetry in the design of the ship.

1.4.2.4 Engineering Complexity

Engineering complexity reflects the experience and qualifications of the engineering design team.

It depends on two factors:

1. Scope of design effort
2. Experience of personnel

Scope of design effort describes the newness of the design task and the sophistication of the technology.

The JSS was determined to be a new design with existing technology because the ship is a unique build of currently existing technology.

Experience of Personnel

Experience of personnel describes design team experience with the tasks being undertaken.

RAND surveyed employee technical skills as part of a study on UK naval industry labour force. Based on its survey, it took technical workers between 6 and 8 years to reach 90% optimum productivity (see Figure 1-2).[33]

[30] Note that it is possible that using old designs may actually result in more design effort being required as a result of trying to adapt an existing design ill-suited to new requirements. Note as well that subject matter experts familiar with TruePlanning® confirmed that they have never come across a new ship that requires no new design effort.

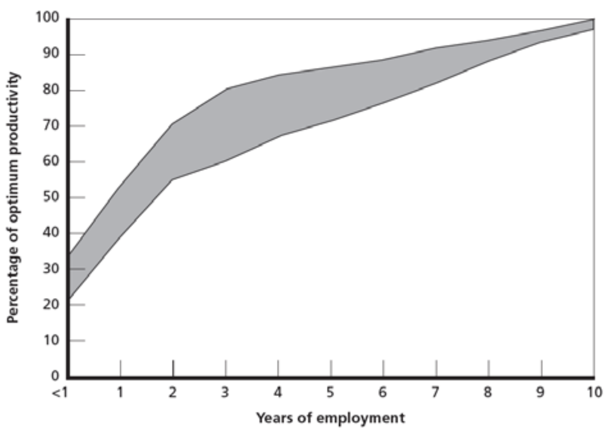
[31] For example, TKMS would have to change the existing design of the Berlin Class's electrical system to accommodate North American standards for voltage and amperage, add two goalposts (refueling masts), and adapt its design to modular construction significantly smaller than those used in Germany. This will require significant new design effort.

[32] The WBS revealed that approximately 22% of its elements could be taken from existing design libraries. This results in 78% of design being created from scratch. That does not mean, however, that the 22% would require no redesign effort. Adapting these designs to ensure they comply with Canadian operating requirement and can be executed in a Canadian shipyard will require additional design effort.

[33] Hans Pung et al, *Sustaining Key Skills in the UK Naval Industry* (Santa Monica, CA: RAND Corporation, 2008) at 35.

> *"This is important to understand because simply employing a worker in a specific technical skill does not intrinsically equate to possessing the associated workforce capability—experience is critical in ensuring that the technical skill becomes a productive capability."*[34]

Figure 1-2: RAND's Productivity Curve by Technical Skill, Build & Support



Source: Hans Pung et al, *supra* note 33 at 35.

The shaded region represents the productivity curve of various technical workers in the shipbuilding industry. RAND cites that, on average, it would take 6–8 years for technical workers to reach at least 90 percent of optimum productivity.

TKMS has designed and built a ship of this nature before. BMT has not. In this case, however, the finalist selected would only form part of the design team. In addition, it will be composed of Seaspan and a third party.

Thus, the personnel of at least two of the parties involved will have no project-specific experience. And, even if TKMS is selected, its personnel do not have project-specific experience designing and manufacturing in Canadian shipyards.

The PBO assumed a design team that has mixed experience. This reflects a value of 1.1.

1.5 Results

As mentioned above, the major cost drivers for the model are:

1. Weight
2. Manufacturing complexity for structure
3. Percent of new structure
4. Percent of design repeat for structure
5. Engineering complexity

As indicated, the inputs for the point estimate were:

1. Weight of 18,469,520 lbs (i.e. Protecteur's weight)
2. MCPLXS of 3.78 (i.e. Protecteur's MCPLXS)
3. Percent of new design of 85% (reflecting the significant redesign work that would be necessary to adapt any design to Canadian operating requirements and make it possible to be built in a Canadian shipyard)
4. Design repeat for structure of 40% (reflecting the fact that there will be some, but not complete, symmetry in the design of the ship)
5. Engineering complexity of 1.1 (i.e. a new design based on existing technology, designed and executed by a team with mixed experience and some product familiarity, thus reflecting Seaspan's current state)

For these values, the model returned a point estimate of approximately $3.28 billion.

This analysis reflects planned project start and finish dates. If the project is put on hold or deviates from the schedule, this could affect the estimate. By way of illustration, RAND Corporation estimates that defence price escalation ranges between 7 and 11% per year.[35]

[34] *Ibid*.

[35] Mark Arena et al, *Why Has the Cost of Navy Ships Risen? A Macroscopic Examination of the Trends in U.S. Naval Ship Costs Over the Past Several Decades* (Santa Monica, CA: RAND Corporation, 2006). For further details see Appendix H: Defence Price Escalation.

As discussed, given that the project is early in its development and characteristics remain uncertain, the PBO varied the inputs in order to provide a sense of how much should be allocated to reduce the likelihood of program failure.

The inputs were varied as follows:

1. Weight was varied between 18,469,520 and 22,833,440 lbs (i.e. the Berlin-class)
2. MCPLXS was varied between 3.39 and 4.25 (i.e. the high and low of MCPLXSs for logistics support ships)[36]
3. Percent of new structure was varied between 50 and 85%[37]
4. Percent of design repeat for structure was varied between 20 and 50%[38]
5. Engineering complexity was varied between 0.9 and 1.1 (i.e. new design, existing technology designed and executed by a team with extensive experience and familiar with product compared to a team with mixed experience and some product familiarity).

Given the stage of the program and the uncertainty of the inputs, GAO best practice recommends budgeting at no less than a 50% confidence level.[39] For this confidence level, varying the inputs above, the PBO's model returns a value of $4.13 billion.

GAO on Ranges Versus Point Estimates

"Having a range of costs around a point estimate is more useful to decision makers, because it conveys the level of confidence in achieving the most likely cost and also informs them on cost, schedule, and technical risks."[40]

2 Analysis

2.1 Summary

The JSS project includes the acquisition of two Protecteur-class AOR ships.

The objective of the analysis is to determine if the $2.6 billion budget can cover all acquisition costs, inclusive of project management, contingencies, and taxes.

The PBO used a CER model to develop its ICE in the Canadian industrial base, based upon historical AOR ship programs and the JSS requirement.

The analysis was inclusive of JSS development and production costs; operations & support (O&S) costs were excluded.

Development and production costs

Development involves the process of designing and building the first ship in class. Creating a new ship type, even when existing designs are relied upon, is a resource-intensive process. It involves costs of initiation and planning, project management and control, quality assurance, development engineering, tooling, testing, and building the first ship.

Production costs are those costs associated with building the ships that follow. While the first ship in class does not involve any production costs, successive ships in class will have diminishing development costs.

Analogous ship data, including ship class, lightweight displacement, contract year, and production unit cost were obtained through information requests and from publicly available sources. The PBO also collected industry documents to support the analysis.

[36] See 2.2.6 MCPLXS Calibration Process.

[37] While 85% new structure is reasonable and reflective of the work that needs to be undertaken, it is possible that that figure may be lower. In order to enhance the defensibility of its range, PBO adopted a conservative figure for the low end of percent of new structure. This increases the likelihood of the simulation returning results with a lower cost.

[38] 20% represents a pessimistic outcome, but one that nonetheless seems within the range of possibilities given the different systems the ship may ultimately contain.

[39] United States Government Accountability Office, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs* (March 2009), online: GAO <http://www.gao.gov/assets/80/77175.pdf>. (See Appendix B: Costing Methods).

[40] *Ibid.*

The ICE was developed using inputs publicly available and confidentially obtained as parameters based on PBO and PRICE estimation team judgment and modeling best practices. The results are provided in Canadian dollars.

Point estimates are presented in Table 2-1, and risk-adjusted results, which modeled variability in numerous parameters (structural weight, MCPLXS, new design, design repeat and engineering complexity), are shown in Table 2-2.

The point estimates indicate a budget of $3.276 billion will be required to replace the *Protecteur* with two JSSs, within which the model only returns between a 15–20% of results. At the 50th percentile, a budget of $4.1 billion will be required. Table 2-2 carries the cost probability density function values.

Table 2-1: Point Estimates (billions)

Category	Cost
Program/Project	$0.98
Engineering	$1.35
Tooling & Test	$0.13
Manufacturing	$0.50
Quality Assurance	$0.33
Total	**$3.28**

Source: PBO

Three sensitivity analyses were conducted to quantify the impact of a change in a specific cost driver in the ICE. The three analyses were as follows:

1. **Engineering Complexity**. The engineering complexity value, which measures the scope of the design effort and experience of shipyard personnel, was modified from the baseline value to calculate cost impact.
2. **Project Complexity**. The project complexity value, which indicates the complexity of the project in the context of planning and oversight activities, was modified from the baseline value to calculate cost impact.
3. **Quantity**: The procurement quantity was increased from two to three.

The sensitivity analysis identified that project and engineering complexity have a very strong influence on JSS acquisition cost (specifically, the experience of shipyard personnel is seen as the key cost driver). Producing a 3rd ship does not significantly add to program costs, as most of the costs are incurred during the development phase.

Table 2-2: Confidence Levels

Confidence	Cost (billions)
5%	$ 2.70
10%	$ 2.96
15%	$ 3.16
20%	$ 3.32
25%	$ 3.47
30%	$ 3.60
35%	$ 3.74
40%	$ 3.87
45%	$ 3.99
50%	$ 4.13
55%	$ 4.26
60%	$ 4.40
65%	$ 4.56
70%	$ 4.72
75%	$ 4.91
80%	$ 5.13
85%	$ 5.39
90%	$ 5.74
95%	$ 6.31

Source: PBO

2.2 Methodology

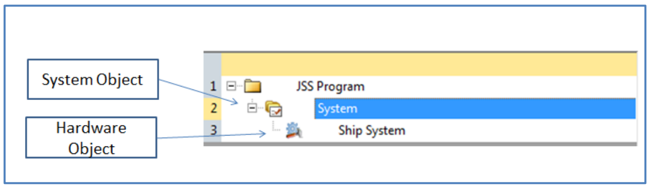
The scope of the analysis is development and acquisition costs of two Protecteur-class AOR ships procured from the Canadian industrial base. Operating and logistic costs are not included.[41] This replacement is referred to as the JSS. The following section describes the techniques and methodologies used to develop the JSS estimate.

[41] The main platform for considerations is the 2009 SOR, while the two excursions are to reflect the original (2006) SOR and the minimal AOR requirements. The necessary model calibrations were made to reflect the Canadian shipbuilding environment.

2.2.1 Cost Estimation Overview

The strategy used for the JSS estimate was to model Systems Engineering/Program Management (SE/PM) (System Catalog) and ship design, development and manufacturing activities (Hardware Catalog). The PBO reviewed and calibrated previous ship systems to decompose relationships between costs and ship size and technology.

Figure 2-1: Product Breakdown Representations



Both cost objects listed above have a specific set of parameters, or cost drivers, which are described below.

Source: TruePlaning®

Both cost objects listed above have a specific set of parameters, or cost drivers, which are described below.

System (SE/PM) Cost Object: JSS requires a system cost object to account for SE/PM. SE/PM, as defined by MIL-HDBK-881, *"covers tasks associated with the overall planning, directing, and controlling of the definition, development, and production of a system [… but] excludes systems engineering and program management effort that can be associated specifically with the equipment (hardware/software) element."*

Hardware Component Object: The JSS is modeled at the total ship level rather than at a lower WBS. Frequently, a large-scale estimate would include numerous hardware components (such as hull, propulsion, etc). However, because ship data was available at the ship (and not sub-system) level, the PBO modeled the JSS estimate at the ship level. The PBO used the model's hardware component object, which includes physical inputs, such as weight (measured by ship displacement), and technical parameters such as MCPLXS, engineering complexity, and percent of new structure, which are listed in Figure 2-2: Hardware Component Input Sheet. Based on these inputs, as well as inherited quantity and schedule data from the system object, the model then calculated costs for development engineering, development manufacturing, development tool & and test, production engineering, production manufacturing, and production tool & and test.

To summarize, the PBO developed an acquisition estimate to include SE/PM, design and manufacturing costs calibrated with analogous ship programs to develop a data driven ROM estimate backed by the CER model, which holds industry average data and estimating relationships, driven by inputs.

Figure 2-2: Hardware Component Input Sheet

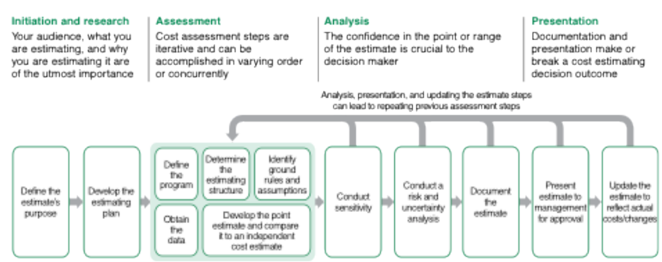
10	Equipment Type	None
11	Operating Specification	**1.60**
12	Weight of Structure	**18,469,520.000**
13	Weight of Electronics	0.000
14	Volume	1.000
15	Manufacturing Complexity for Structure	**3.780**
16	Percent of New Structure	**85%**
17	Percent of Design Repeat for Structure	**40%**
18	Manufacturing Complexity for Electronics	7.000
19	Percent of New Electronics	100%
20	Percent of Design Repeat for Electronics	0%
21	Engineering Complexity	**1.100**

Source: TruePlaning®

2.2.2 Cost Estimation Process

The cost estimation process has been adapted from the GAO 12-step estimating approach (Figure 2-3).

Figure 2-3: Cost Estimation Approach



Source: U.S. GAO, *supra* note 39.

The GAO steps, with specific aspects of the JSS ICE, are listed below:

1. *Define the estimate's purpose:* The purpose is to estimate JSS acquisition costs.
2. *Develop the estimating plan:* The cost team used TruePlanning® model.
3. *Define the program:* The program was defined as replacement of the Protecteur built in Canada according to Government of Canada procurement rules.
4. *Determine the estimating approach:* The estimating approach for each cost object was based upon data availability.
5. *Identify ground rules & assumptions (GR&A):* ICE GR&A were documented for all alternatives.
6. *Obtain the data:* Physical data from the Protecteur were collected (size, weight, etc), which served as the JSS baseline. Analogous ship production cost data were collected and normalized, which supported MCPLXS calibration.[42]
7. *Develop the point estimate:* The cost estimate was developed in an iterative fashion, based upon known values (ship class, lightweight tonnage) and key parameters or cost drivers, such as MCPLXS, design repeat project complexity and engineering complexity. This ICE reflects "Canadian realities" (estimated in Canadian dollars, Canadian taxes, and shipyard capabilities).
8. *Conduct sensitivity:* Sensitivity analysis was developed around key cost drivers, measuring the cost impact of changes. Separate sensitivity analyses were undertaken, focused on engineering complexity, project complexity, MCPLXS, and acquisition quantity.
9. *Conduct risk and uncertainty analysis:* A risk assessment/analysis was conducted following the completion of the point estimates and is documented in Section 2.3.5. Risk analysis modeled a triangular distribution of likely ranges of possible weight, MCPLXS, percent new structure, design repeat, and engineering complexity.

Most work focused around GAO steps 5–9. Details of the steps involved in data collection, calibration, parametric modeling, sensitivity and risk analysis are listed below.

The cost team collected information from publicly available and confidential sources. The data was reviewed and validated by SMEs at PRICE Systems. Industry benchmarks were also researched, along with analogous programs and publicly available information, which were incorporated into the ICE. These parameters inputs were validated. Full listings of key input parameters, for each alternative's technology systems, are displayed in Appendix D: Model Inputs.

2.2.3 Data Collection and Data Sources

One of the key aspects of cost analysis is data collection. The PBO collected programmatic, technical and cost data at various stages of the analysis. A listing of data files obtained during the study period is listed Table 2-3.

[42] Unit production cost data is assumed to exclude program-level SE/PM. Thus, the calibration file included a Hardware component only, and excluded a System Cost Object. However, the Hardware Cost object does include equipment-specific SE/PM.

Table 2-3: Data Collection Summary

Documents/ Interviews	Source
JSS Schedule	http://www.navy.forces.gc.ca/protecteur/1/1-s_eng.asp?category=17&title=578
JSS Statement of Operational Requirement, V5.5, 5/25/2009	DND
An Analysis of the Navy's Fiscal Year 2013 Shipbuilding Plan, 7/2012	US Congressional Budget Office
Internal Audit of JSS Project, Chief Review Services, 11/2011	http://www.crs-csex.forces.gc.ca/reports-rapports/pdf/2011/P0934-eng.pdf
JSS Schedule	http://www.materiel.forces.gc.ca/en/jss-sch.page?
Vancouver Shipyard Facility Brochure	http://seaspanfornsps.com/wp-content/uploads/2011/06/2011-Vanship-Brochure.pdf
Vancouver Drydock Facility Brochure	http://seaspanfornsps.com/wp-content/uploads/2011/06/2011-VDC-Brochure.pdf
Vancouver Drydock History Brochure	http://seaspanfornsps.com/wp-content/uploads/2011/06/Vessels-built-at-Vancouver-Shipyards-June-16-2011.pdf
JSS Project Status	http://www.materiel.forces.gc.ca/en/jss.page
Protecteur Acquisition Contract, Treasury Board, 12/16/66	Treasury Board

Source: PBO

2.2.4 Ground Rules and Assumptions

Ground rules & assumptions were followed. The estimate:

- includes development and production costs
- is calculated in then-year Canadian dollars
- assumes 2.7% annual escalation
- assumes one prototype and one production system
- assumes development begins March 1, 2014
- assumes development first article (prototype) is delivered by April 30, 2018
- assumes production first article (second ship) delivered by September 30, 2019
- assumes 13% HST applied to contractor costs

2.2.5 Data normalization process

PBO obtained database of ship data points, which included the following fields:

- Ship class
- Navy (country)
- Type of ship
- Number built
- Country of origin
- Shipyard
- Status
- Year(s) of construction
- Number built
- Contract year
- Size (tonnes light)
- Size (tonnes heavy)
- Complement (crew)
- Production cost per ship
- Cost type
- Cost notes

The database included fleet replenishment ships, fleet logistics tankers, JSSs, fast combat support ships (FCS), T-AKE dry cargo and ammunition ships, and oilers, with construction dates ranging from the 1980s to present. Since the historical data was provided at the ship level, data cleansing, normalization and calibration were done at the ship level. Thus, the JSS ICE is also modeled and estimated at the ship level. The key data elements required for the calibration are the weight and the unit production cost. The historical cost data provided weight, contract year, and cost of each ship. Production costs were normalized to 2012 US dollars, based upon Naval Center for Cost Analysis indices, before calibration. Data points were removed where the shipbuilding was incomplete or costs included development as well as production. The intent of the normalization process was to eliminate the cost variability due to inflation and establish known production costs in a constant BY dollars. Table 2-4 below displays the normalized ship data.

Protecteur data was obtained from a 1966 acquisition contract. The contract identified procurement of 2 ships for a cost of $51.7 million.

Table 2-4: Normalized Data

Ship or Class	Type of Ship	Base Year	Tonnes Light	2012 Cost ($M)
Cantabria	Fleet Replenishment Ship	2005	9,800	$293
Berlin	Fleet Logistic Tanker	1997	10,360	$201
Berlin	Fleet Logistic Tanker	1998	10,360	$180
Karel Doorman (JSS)	Joint Support Ship	2009	20,703	$408
Amsterdam	Fast Combat Support Ship	1995	17,040	$254
Lewis & Clark (1 in class)	T-AKE Dry Cargo and Ammunition Ship	2001	23,852	$498
Henry J. Kaiser	Oiler	1992	40,000	$149
Wave	Auxilary Oiler	1997	31,500	$320
Protecteur	Oiler	1966	8,380	$116

Source: PBO

2.2.6 MCPLXS Calibration Process

Following data normalization, the next step involved calculating appropriate MCPLXS values, based upon the light displacement weight (weight of the ship excluding cargo, fuel, ballast, stores, passengers, and crew), operating specification, and normalized unit production cost. The calibration process determines the optimal MCPLXS value to produce a known unit production cost. The final step of the calibration process was to select an appropriate MCPLXS value for the JSS.

The operating specification value indicates the end user's requirements based on the planned operating environment for the hardware piece (ground, air, space, sea). It is a measure of the portability, reliability, structuring, testing and documentation requirements for acceptable contract performance. Operating specification has a significant impact on development engineering costs. The operating specification value was set to the “Military Ship” value of 1.6, as listed in Figure 2-4: Operating Specification.

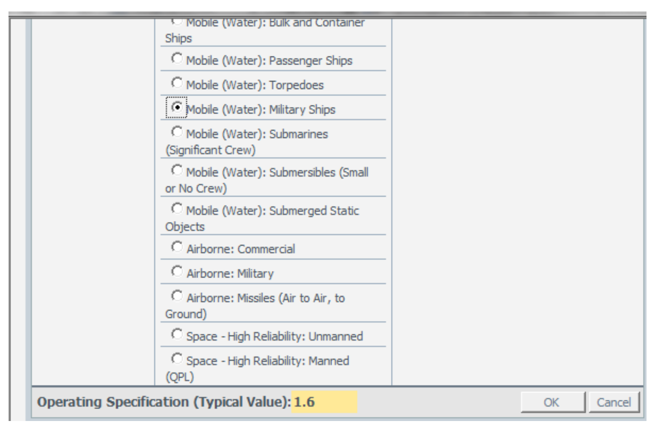
Weight was provided in the PBO ship database and was converted from metric tonnes to pounds for purposes of model input. Production unit costs, as described in Table 2-4, were converted into 2012 dollars prior to the calibration.

Calibrated MCPLXS values are listed in Table 2-5. The production unit cost (actual) column lists the production unit costs obtained from the database, while the amortized unit production cost lists the production costs calculated by the model from calibrated MCPLXS values.

Figure 2-5 depicts the exponential relationship between MCPLXS and the unit cost per weight of all the known ship data points, with an R-squared value of 89%. The MCPLXS values varied from 3.39 to 4.25 with a median value of 3.9.

Discussions within the PBO and with SMEs resulted in the selection of the Protecteur ship’s calibrated complexity value of 3.78 (Table 2-5) as the most conservative JSS complexity value. PBO identified that the JSS will at a minimum be similar to the Protecteur. Costing a direct replacement of the Protecteur, therefore, would provide a defensible cost estimating approach, as there is high confidence in the Protecteur cost information, relative to the other data points. The Protecteur costs were based from data obtained in an acquisition contract. The selected JSS MCPLXS falls near the median of the boundary of analogous ship data points.

Figure 2-4: Operating Specification



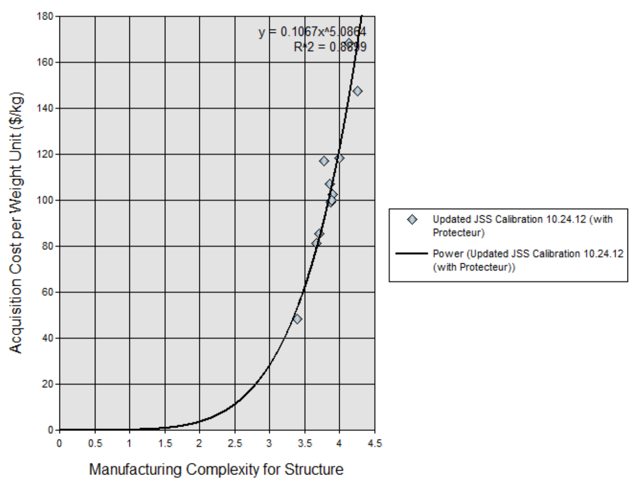
Source: TruePlanning®

Table 2-5: Calibration Results

Cost Object Name	Cost Object Custom Name	Manufacturing Complexity for Structure	Weight of Structure (lb)	Development Cost (Estimated)	Production Cost (Actual)
System Folder	JSS Calibration				
Hardware Component	Cantabria	4.13	21,599,200	$ 1,355,957,525	$ 293,580,924
Hardware Component	Berlin	3.71	44,608,960	$ 1,529,768,917	$ 201,268,043
Hardware Component	Berlin(2)	3.67	44,608,960	$ 1,463,061,180	$ 179,772,710
Hardware Component	Karel Doorman (JSS)	3.99	45,629,164	$ 2,043,902,043	$ 408,158,202
Hardware Component	Amsterdam	3.86	37,556,160	$ 1,570,897,691	$ 253,779,518
Hardware Component	Lewis & Clark	4.03	52,569,808	$ 2,333,265,242	$ 497,414,846
Hardware Component	Henry J. Kaiser(2)	3.39	88,160,000	$ 1,781,233,214	$ 148,851,420
Hardware Component	Wave(2)	4.25	63,563,189	$ 3,276,716,539	$ 975,502,209
Hardware Component	Protecteur	3.78	18,771,200	$ 881,608,890	$ 115,890,891
Min	3.39				
Median	3.89				
Max	4.25				
Selected Value (Protecteur)	3.78				

Source: TruePlanning®

Figure 2-5: Manufacturing Complexity vs Acquisition Cost per Unit Weight



Source: TruePlanning®

Table 2-6: Ship Database Costs

	Costs : Updated JSS Calibration 10.: Currency in USD ($) (as spent)	Total	Development	Production
1	Cantabria	1,649,538,4...	1,355,957,525	293,580,924
2	Berlin	1,731,036,959	1,529,768,917	201,268,043
3	Berlin(2)	1,642,833,890	1,463,061,180	179,772,710
4	Karel Doorman (JSS)	2,452,060,245	2,043,902,043	408,158,202
5	Amsterdam	1,824,677,209	1,570,897,691	253,779,518
6	Lewis & Clark	2,830,680,088	2,333,265,242	497,414,846
7	Lewis & Clark(2)	2,440,586,637	2,071,667,115	368,919,522
8	Lewis & Clark(3)	2,384,754,492	2,032,887,787	351,866,705
9	Lewis & Clark(4)	2,363,411,405	2,017,980,666	345,430,739
10	Lewis & Clark(5)	3,323,163,918	2,643,096,511	680,067,407
11	Lewis & Clark(6)	3,298,838,653	2,628,233,884	670,604,769
12	Lewis & Clark(7)	2,382,709,386	2,031,461,484	351,247,903
13	Lewis & Clark(8)	3,734,700,666	2,886,903,814	847,796,853
14	Henry J. Kaiser(2)	1,930,084,634	1,781,233,214	148,851,420
15	Wave(2)	4,252,218,748	3,276,716,539	975,502,209
16	Protecteur	997,499,781	881,608,890	115,890,891

Source: TruePlanning®

2.2.7 Parametric Model Development

To build the parametric model, the PBO chose to develop a "two box" estimate, to include a SE/PM and hardware component, and not a detailed subsystem level estimate. The database that was used to support MCPLXS calibration was at the system level (i.e. production costs were provided at the system level), which served to support the decision to estimate in a similar structure. Subsystem level analysis was not feasible given data constraints.

The acquisition quantity was set at two, acquisition schedule according to the RPP, and system weight—which assumes the Protecteur weight—at 8,380 tonnes light or 18,469,520 pounds.[43] One prototype and one production ship were estimated in Canadian dollars with an annual escalation rate of 2.7%, consistent with DND escalation rates.

The key system object costs drivers are multiple site development, vendor interface complexity and project complexity.

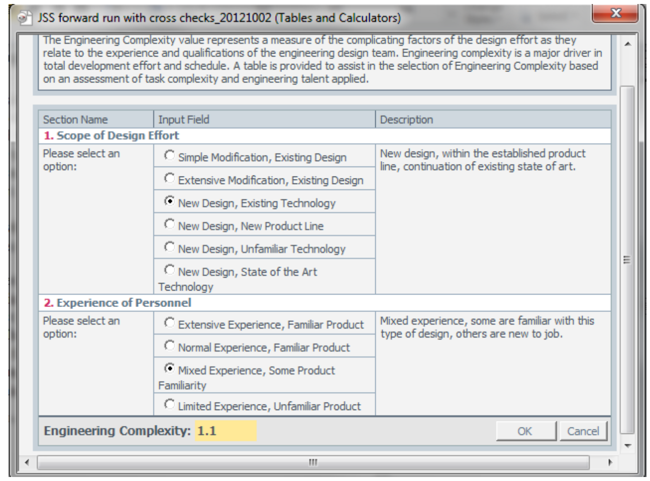
[43] Royal Canadian Navy, *HMCS Protecteur – About the Ship – Ship's Characteristics*, (2 June 2003), online: Royal Canadian Navy <http://www.navy.forces.gc.ca/protecteur/1/1-s_eng.asp?category=17&title=578>.

Multiple site development assumes two to three development locations with poor communication. High vendor interface and supervision requirements were assumed. Project complexity indicates the complexity of the project in the context of planning and oversight activities. The JSS Project is assumed to have high project complexity (Figure 2-7), representative of a large, complex project.[44]

The key hardware component object cost drivers are weight, operating specification, percent of new structure, percent design repeat for structure, and engineering complexity. Operating specification was set to Mobile-Military Ship. MCPLXS, as described in Table 2-5, was set to a value of 3.78. Engineering complexity measures the scope of the design effort and experience of shipyard personnel (Figure 2-7). PBO selected new design/existing technology and mixed team experience/some product familiarity, reflecting a value of 1.1. A value of 1 would represent average or typical engineering complexity, thus the value of 1.1 represents a higher and more expensive degree of engineering complexity. New structure percentage of 85% and design repeat of 40% were selected.

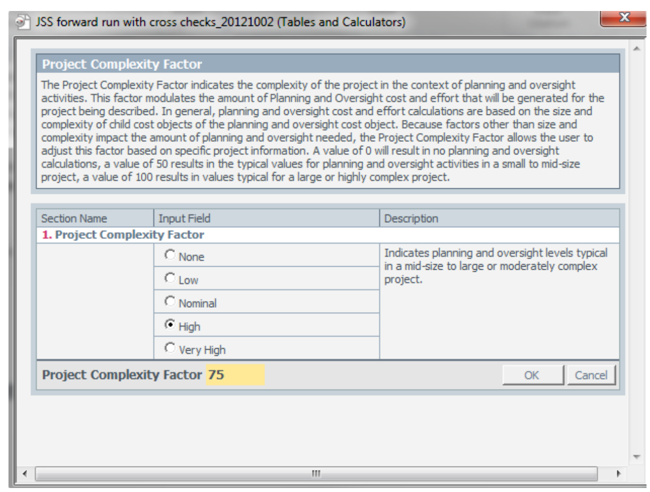
Other parameters were left at default settings. A full listing and substantiation of the parameters is listed in Appendix D: Model Inputs.

Figure 2-6: JSS Engineering Complexity



Source: TruePlanning®

Figure 2-7: JSS Project Complexity



Source: TruePlanning®

2.3 Analysis

The analysis section contains the point and risk-adjusted estimates and sensitivity analysis.

2.3.1 Point Estimate

The JSS point estimate is $3.276 billion, which includes $3.044 billion in development and $.232 billion in production costs, as listed in Table 2-7. Development costs represent non-recurring engineering and prototype development. Production includes the SE/PM and manufacturing costs of the

[44] In this case, there will be three active locations (i.e. the client (DND), the designer (TKMS or BMT), and Seaspan). Federal procurement rules put certain restrictions on the ability of contractors to communicate with federal employees. Since the Government must facilitate communication between the shipyard and the designer, delays or restrictions are likely. Where the communication between three active locations is characterized as poor, TruePlanning ascribes a value of 2.5.

second ship. To emphasize, the $.232 billion applies only to the second ship.

Table 2-7: Activity Name by Phase Results

	Costs : System - [System] Currency in CAD ($) (as spent)	Total	Development	Production
1	Project Initiation and Planning for Development	75,215,363	75,215,363	
2	Project Management and Control for Development	409,225,051	409,225,051	
3	Quality Assurance Management for Development	304,848,809	304,848,809	
4	Configuration Management for Development	278,622,672	278,622,672	
5	Vendor Management for Development	54,602,647	54,602,647	
6	Documentation for Development	107,455,046	107,455,046	
7	Project Initiation and Planning for Production	4,137,313		4,137,313
8	Project Management and Control for Production	18,698,027		18,698,027
9	Quality Assurance Management for Production	20,850,990		20,850,990
10	Configuration Management for Production	17,160,943		17,160,943
11	Vendor Management for Production	3,218,020		3,218,020
12	Documentation for Production	7,938,203		7,938,203
13	Development Engineering	1,320,388,586	1,320,388,586	
14	Development Manufacturing	365,961,985	365,961,985	
15	Development Tooling and Test	128,161,644	128,161,644	
16	Production Engineering	29,360,129		29,360,129
17	Production Manufacturing	129,538,803		129,538,803
18	Production Tooling and Test	1,100,276		1,100,276
19	Total	3,276,484,505	3,044,481,802	232,002,703

Source: TruePlanning®

2.3.2 Sensitivity Analysis

In this sensitivity analysis, the PBO analyzed the cost impact of the project complexity, engineering complexity, MCPLXS, and quantity.

2.3.2.1 Project Complexity Sensitivity

In this analysis, using the model's sensitivity analyzer, the PBO set the project complexity values range from low (value of 25) to very high (value of 100). The project complexity definitions are detailed below.

- Low (25): Planning and oversight levels typical in a small or simple project.
- Nominal (50): Planning and oversight levels typical in a small or mid-size project.
- High (75): Planning and oversight levels typical in a mid-size to large or moderately complex project.
- Very high (100): Planning and oversight levels typical in a large or highly complex project.

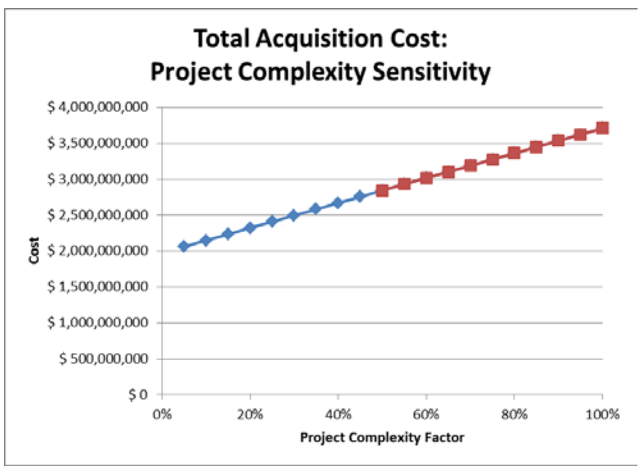
Table 2-8 and Figure 2-8 display results of the project complexity sensitivity analysis (note that the baseline in a total cost of $3.276 billion assumes high project complexity). The delta between a nominal and high project complexity is estimated at $.434 billion.

Table 2-8: Project Complexity Sensitivity Analysis

Project Complexity Factor	Estimated Cost (billion)
0	$ 1.97
5	$ 2.06
10	$ 2.15
15	$ 2.23
20	$ 2.32
25	$ 2.41
30	$ 2.50
35	$ 2.58
40	$ 2.67
45	$ 2.76
50	$ 2.84
55	$ 2.93
60	$ 3.02
65	$ 3.10
70	$ 3.19
75	$ 3.28
80	$ 3.36
85	$ 3.45
90	$ 3.54
95	$ 3.62
100	$ 3.71

Source: PBO

Figure 2-8: Project Complexity Sensitivity Chart



Source: PBO

2.3.2.2 Engineering Complexity Sensitivity

Engineering complexity value is a measure of the scope of the design effort and experience of shipyard personnel.

In this analysis, using the model's sensitivity analyser, PBO set the engineering complexity values from 0.1 to 1.5. The engineering complexity parameter settings are listed in Table 2-9.

Table 2-9: Engineering Complexity Values

Scope of Design Effort	Experience of Personnel: Extensive, Familiar Product	Experience of Personnel: Normal, Familiar Product	Experience of Personnel: Mixed, Some Product Familiarity	Experience of Personnel: Limited, Unfamiliar Product
Simple Modification, Existing Design	0.2	0.3	0.4	0.5
Extensive Modification, Existing Design	0.6	0.7	0.8	0.9
New Design, Existing Technology	0.9	1	1.1	1.2
New Design, New Product Line	1	1.2	1.4	1.6
New Design, Unfamiliar Technology	1.3	1.6	1.9	2.2
New Design, State of Art Technology	1.9	2.3	2.7	3.1

Source: PBO

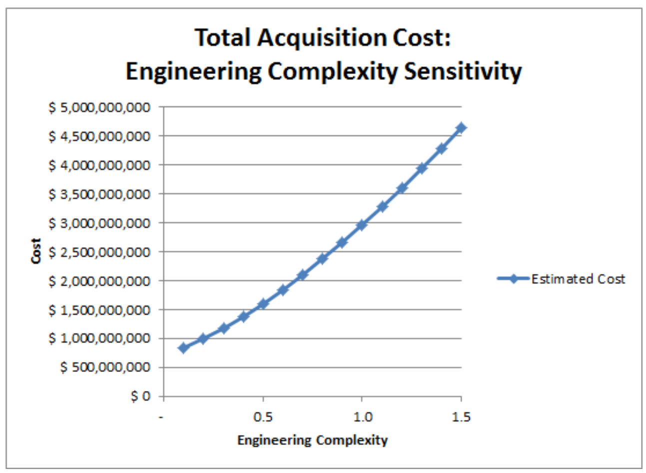
Table 2-10 and Figure 2-9 display the total cost impact due to engineering complexity. The impact of increasing the engineering complexity from 1.0 (new design, existing technology and normal experience, familiar product) to 1.1 (new design, existing technology and mixed experience, some product familiarity) is $.311 billion. It is noted that less experienced shipyard personnel, with no change in the scope of design effort, will have a significant cost impact on the program.

Table 2-10: Total Cost Sensitivity on Engineering Complexity

Engineering Complexity	Estimated Cost (billions)
0.1	$ 0.8435
0.2	$ 0.9920
0.3	$ 1.1721
0.4	$ 1.3766
0.5	$ 1.6017
0.6	$ 1.8447
0.7	$ 2.1038
0.8	$ 2.3775
0.9	$ 2.6648
1	$ 2.9647
1.1	$ 3.2765
1.2	$ 3.5994
1.3	$ 3.9330
1.4	$ 4.2767
1.5	$ 4.6302

Source: PBO

Figure 2-9: Total Cost Sensitivity on Engineering Complexity



Source: PBO

2.3.2.3 MCPLXS Sensitivity

The MCPLXS value represents a technology index for the structural portion of the ship. MCPLXS is a measure of the ship's technology, its producibility (material machining and assembly tolerances, machining difficulty, surface finish, etc.), and yield. MCPLXS is a major cost and schedule driver.

The MCPLXS value (3.78) was determined from the Protecteur ship calibration. MCPLXS values from analogous program calibration ranged from 3.38 to 4.25.

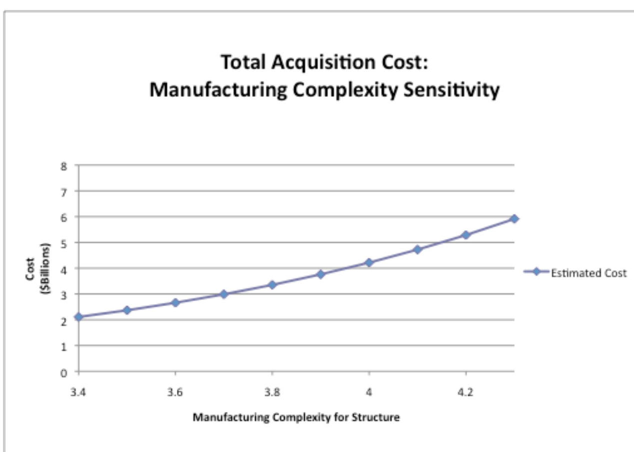
In this analysis, using the model's sensitivity analyser, the PBO set the MCPLXS values from 3.4 to 4.3. Table 2-11 and Figure 2-10 display the impact of total cost due to MCPLXS. The total costs within the calibrated MCPLXS values ranged from $2.109 billion (MCPLXS: 3.4) to $5.285 billion (MCPLXS: 4.2). Figure 2-10 displays the non-linear relationship between MCPLXS and total acquisition cost.

Table 2-11: Total Cost Sensitivity on MCPLXS

MCPLXS	Estimated Cost (billions)
3.4	$ 2.11
3.5	$ 2.37
3.6	$ 2.66
3.7	$ 2.99
3.8	$ 3.35
3.9	$ 3.76
4.0	$ 4.22
4.1	$ 4.72
4.2	$ 5.28
4.3	$ 5.91

Source: PBO

Figure 2-10: Total Cost Sensitivity on MCPLXS



Source: PBO

2.3.2.4 Production Quantity Sensitivity

The final sensitivity reviewed the cost impact of delivering a third ship. The first ship is assumed to be a prototype. There is no increase in development costs, which is inclusive of the prototype system. Production costs are increased from $.232 billion to $.357 billion (a $.125 billion increase, or 54%) due to manufacturing an additional ship. The costs for two ships are not twice that of a single ship due to economies of scale in the procurement phase and learning effects on both labor and materials.

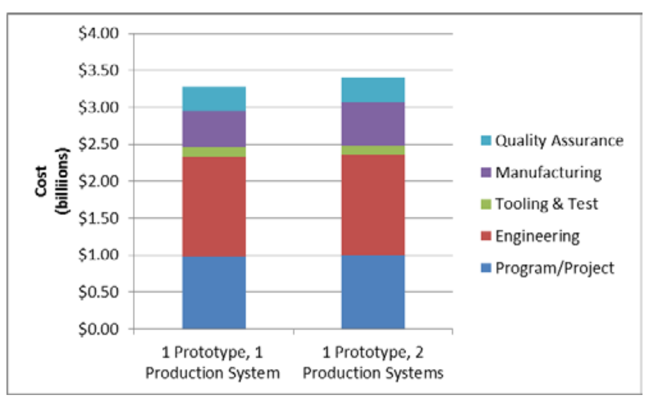
Table 2-12: Production Quantity Sensitivity Results

1 Prototype, 1 Production System (billions)	
Program/Project	$0.976
Engineering	$1.350
Tooling & Test	$0.129
Manufacturing	$0.496
Quality Assurance	$0.326
Total	$3.276

1 Prototype, 2 Production Systems (billions)	
Program/Project	$1.002
Engineering	$1.350
Tooling & Test	$0.130
Manufacturing	$0.583
Quality Assurance	$0.336
Total	$3.401

Source: PBO

Figure 2-11: Production Quantity Chart



Source: PBO

2.3.3 Schedule Analysis

Schedule analysis modeled the cost penalty associated with constraining the schedule to deliver two ships by September 2019, compared against an "unconstrained schedule" estimate.

The baseline schedule assumes the program begins in March 1, 2014, development first article milestone (prototype) on April 30, 2018, and production first article on September 30, 2019. The unconstrained schedule assumes a development start date of March 2014, and the model forecasts an optimal schedule.

The optimal schedule forecasts production first article in April 2023, which is a 3 ½ year extension from the baseline schedule. Schedule parameters for the baseline and unconstrained schedule are displayed in Figure 2-12 through Figure 2-15.

These results indicate that cost savings associated with extending the schedule outweigh the effects of defence price escalation. This does not mean, however, that the schedule ought to be extended, as operational requirements and vendor resources may not permit extension.

The "schedule penalty", which measures additional costs required to complete the project within six years, is $.852 billion, as displayed in Table 2-13: Schedule Analysis Summary. This includes costs to complete the development effort in a compressed time period, ramp up the production line, and stay within the critical schedule path. Significant resources have to be added earlier in the development and production period to complete and meet the compressed schedule, resulting in higher costs and greater risk.

Figure 2-12: System Object Schedule (Baseline)

		Start Date	End Date
1	Project Initiation and Planning for Development	3/1/2014	9/30/2018
2	Project Management and Control for Development		9/30/2018
3	Quality Assurance Management for Development		9/30/2018
4	Configuration Management for Development		9/30/2018
5	Vendor Management for Development		9/30/2018
6	Documentation for Development		9/30/2018
7	Project Initiation and Planning for Production		9/30/2019
8	Project Management and Control for Production		9/30/2019
9	Quality Assurance Management for Production		9/30/2019
10	Configuration Management for Production		9/30/2019
11	Vendor Management for Production		9/30/2019
12	Documentation for Production		9/30/2019
13	Project Initiation and Planning for Operation and Support		
14	Project Management and Control for Operation and Su...		
15	Quality Assurance Management for Operation and Sup...		
16	Configuration Management for Operation and Support		
17	Vendor Management for Operation and Support		
18	Documentation for Operation and Support		

Source: TruePlanning®

Figure 2-13: Hardware Component Schedule (Baseline)

		Start Date	End Date
1	Development Engineering	3/1/2014	4/30/2018
2	Development First Article Milestone	4/30/2018	4/30/2018
3	Development Manufacturing		4/30/2018
4	Development Tooling and Test		4/30/2018
5	Production First Article Milestone	9/30/2019	9/30/2019
6	Production Engineering		9/30/2019
7	Production Manufacturing		9/30/2019
8	Production Tooling and Test		9/30/2019

Source: TruePlanning®

Figure 2-14: System Object Schedule (Unconstrained)

		Start Date	End Date
1	Project Initiation and Planning for Development	3/1/2014	
2	Project Management and Control for Development		
3	Quality Assurance Management for Development		
4	Configuration Management for Development		
5	Vendor Management for Development		
6	Documentation for Development		
7	Project Initiation and Planning for Production		
8	Project Management and Control for Production		
9	Quality Assurance Management for Production		
10	Configuration Management for Production		
11	Vendor Management for Production		
12	Documentation for Production		
13	Project Initiation and Planning for Operation and Support		
14	Project Management and Control for Operation and Su...		
15	Quality Assurance Management for Operation and Sup...		
16	Configuration Management for Operation and Support		
17	Vendor Management for Operation and Support		
18	Documentation for Operation and Support		

Source: TruePlanning®

Figure 2-15: Hardware Object Schedule (Unconstrained)

		Start Date	End Date
1	Development Engineering	3/1/2014	
2	Development First Article Milestone		
3	Development Manufacturing		
4	Development Tooling and Test		
5	Production First Article Milestone		
6	Production Engineering		
7	Production Manufacturing		
8	Production Tooling and Test		

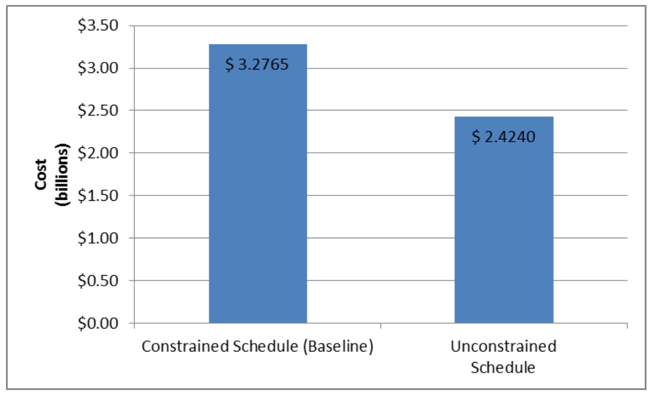
Source: TruePlanning®

Table 2-13: Schedule Analysis Summary (billions)

Fiscal Year	Baseline	Unconstrained Schedule	Schedule Penalty
2014	$ 0.4933	$ 0.1519	(0.3414)
2015	$ 0.9548	$ 0.3201	(0.6348)
2016	$ 0.8973	$ 0.3390	(0.5583)
2017	$ 0.6406	$ 0.2973	(0.3434)
2018	$ 0.2410	$ 0.4226	$ 0.1816
2019	$ 0.0493	$ 0.4193	$ 0.3700
2020		$ 0.2329	$ 0.2329
2021		$ 0.1118	$ 0.1118
2022		$ 0.1139	$ 0.1139
2023		$ 0.0152	$ 0.0152
Total	$ 3.2765	$ 2.4240	(0.8525)

Source: PBO

Figure 2-16: JSS Schedule Analysis



Source: PBO

2.3.4 Cross-checks

As a cross-check, PBO developed acquisition cost estimates for the Cantabria, Berlin, Karel Doorman, Amsterdam, Lewis & Clark. The development and production cost of each ship was estimated using the model with the same technical and programmatic input parameters as JSS except MCPLXS (such as quantity, schedule, project complexity, vendor interface complexity, engineering complexity, percent of new structure, or percent of design repeat). Each ship estimate was based on the assumption that ships would be built today, in the same shipbuilding environment as the JSS. Each ship's weight was based on the actual ship weight, and its MCPLXS was based on its calibrated MCPLXS value. The JSS project is assumed to be built and executed in a ship building environment that is not experienced in building similar ships with a limited

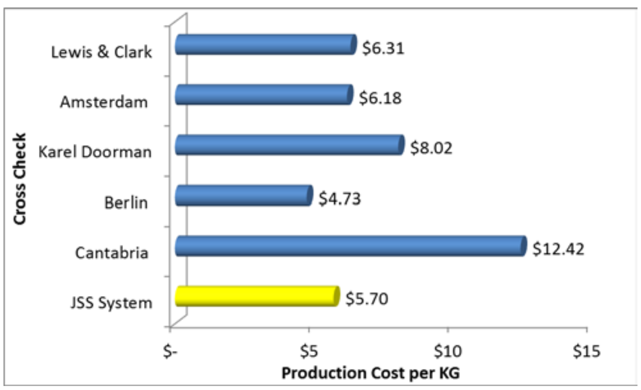
experienced engineering team. The results are shown in Table 2-14. The JSS cost per weight (kg) is within 17% of the Berlin, Amsterdam and Lewis & Clark ship estimates.

Table 2-14: Total Cost Cross-check (CDN TY$)

	Total Cost (billions)	Weight (lbs)	MCPLXS
JSS	4.1	18,469,520	3.9
Cantabria	5.8	21,599,200	4.1
Berlin	4	22,833,440	3.7
Karel Doorman	9.1	45,629,164	4.0
Amsterdam	6.9	37,556,160	3.9
Lewis & Clark	9.3	52,569,808	4.0

Source: PBO

Figure 2-17: Cost per kg Cross-check



Source: PBO

Note: These figures assume no redesign work necessary to adapt the ship to Canadian operating requirements and building in Canada.

2.3.5 Risk Analysis

Due to the inherent uncertainty involved in developing comprehensive cost estimates, the cost team utilized the model's in-built risk analysis in an attempt to quantify the risk associated with individual parameters and assumptions.

Risk analysis modeled a triangular distribution of likely ranges of possible weight, MCPLXS, percent new structure, design repeat, and engineering complexity.

The MCPLXS range was determined from the ranges in the calibrated complexity values.

The weight assumes that the JSS weight will not be less than that of the Protecteur, but could increase by approximately 25%.

The percent new structure value of 85% represents a conservative (minimal design reuse) position, thus the point and pessimistic values are identical, and the optimistic value of 50% was based on SME input.

Percent design repeat assumes an optimistic input of a symmetrical design (50% repeat), while the pessimistic input assumes much less design repeat.

Engineering complexity in the baseline and pessimistic scenario assume new design/existing technology and mixed experience/some product familiarity, while the optimistic scenario is based upon New Design/Existing Technology and Extensive Experience/Familiar Product.

It is important to note that the wider the uncertainty around the input parameters, the greater the probability of the estimate exceeding the "point" or "most likely" estimate. This uncertainty is expressed in terms of a "confidence" level.

A point estimate at the 80% confidence level means the estimate has a 20% chance of exceeding the point estimate at 80% chance of coming in at or below the point estimate.

Table 2-15: Risk Parameters

	Baseline	Pessimistic	Optimistic
Weight of Structure (lbs)	18,469,520	22,833,440	18,469,520
MCPLXS	3.78	4.25	3.39
% New Structure	85%	85%	50%
% Design Repeat for Structure	40%	20%	50%
Engineering Complexity	1.1	1.1	0.9

Source: PBO

Figure 2-18: JSS Cumulative Distribution

Source: TruePlanning®

Figure 2-19: JSS Risk-Adjusted Results

Confidence	Total Acquisition Costs (in billions)
5%	$ 2.70
10%	$ 2.96
15%	$ 3.16
20%	$ 3.32
25%	$ 3.47
30%	$ 3.60
35%	$ 3.74
40%	$ 3.87
45%	$ 3.99
50%	$ 4.13
55%	$ 4.26
60%	$ 4.40
65%	$ 4.56
70%	$ 4.72
75%	$ 4.91
80%	$ 5.13
85%	$ 5.39
90%	$ 5.74
95%	$ 6.31
Standard Deviation	$ 1.12
Mode	$ 3.86
Mean	$ 4.27

Source: PBO

2.4 Observations

Risk analysis identified a cost risk range of $2.7–6.3 billion. The analysis indicates that it is not feasible to produce two AOR ships within the current budget holding all specifications and other inputs constant. The budget envelope of $2.6 billion is unlikely to be feasible given Canadian shipyard realities, schedule constraints, and likely "unknown-unknowns" that have yet to be identified. Additionally, the FOC date of September 2019 is optimistic, and holding to this schedule could result in up to $.8 billion in additional costs.

At the 50th percentile confidence, JSS acquisition costs are predicted to be $4.13 billion, which represents a 26% increase above the point estimate. The reason for the significant increase is because the cone of uncertainty is quite wide at a pre-design stage. As the program advances and inputs become certain, the spread of values provided for different confidence levels will narrow (see Figure 3-1).

3 Appendix A: Interpreting Parametric Cost Estimates on a Budget Envelope

When generating a parametric cost estimate, the cost estimator may choose to present the result as either a point estimate or a range. Depending on the circumstances, one or both of these descriptions of the results may be appropriate. The purpose of this annex is to provide the reader with a better understanding of how, in this case, the decision was made to present the JSS estimate as range as opposed to a point estimate.

Excerpts from the GAO's Cost Estimating and Assessment Guide

Point Estimates Alone Are Insufficient for Good Decisions (page 154)

"Since cost estimates are uncertain, making good predictions about how much funding a program needs to be successful is difficult. In a program's early phases, knowledge about how well technology will perform, whether the estimates are unbiased, and how external events may affect the program is imperfect. For management to make good decisions, the program estimate must reflect the degree of uncertainty, so that a level of confidence can be given about the estimate.

Quantitative risk and uncertainty analysis provide a way to assess the variability in the point estimate. Using this type of analysis, a cost estimator can model such effects as schedules slipping, missions changing, and proposed solutions not meeting user needs, allowing for a known range of potential costs. Having a range of costs around a point estimate is more useful to decision makers, because it conveys the level of confidence in achieving the most likely cost and also informs them on cost, schedule, and technical risks.

Point estimates are more uncertain at the beginning of a program, because less is known about its detailed requirements and opportunity for change is greater. In addition, early in a program's life cycle, only general statements can be made. As a program matures, general statements translate into clearer and more refined requirements that reduce the unknowns. However, more refined requirements often translate into additional costs, causing the distribution of potential costs to move further to the right."

Budgeting to a Realistic Point Estimate (page 158)

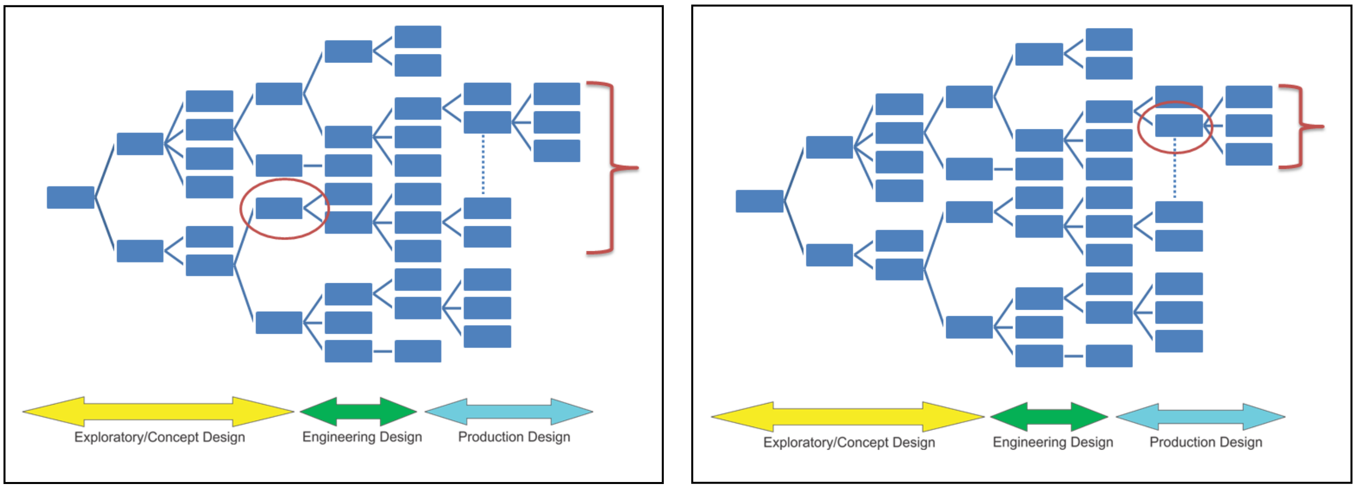
"Management can use the data in an S curve to choose a defensible level of contingency reserves. While no specific confidence level is considered a best practice, experts agree that program cost estimates should be budgeted to at least the 50 percent confidence level, but budgeting to a higher level (for example, 70 percent to 80 percent, or the mean) is now common practice. Moreover, they stress that contingency reserves are necessary to cover increased costs resulting from unexpected design complexity, incomplete requirements, technology uncertainty, and industrial base concerns, to name a few uncertainties that can affect programs."

The JSS procurement may be viewed as a series of decisions, the first among them the decision of DND to replace the Protecteur-class AOR. By the time that this new acquisition was announced, a number of other decisions had been made, including: the total budget of the project, when the navy would take delivery of the ship, and the high-level features of the ship. Since the announcement, further decisions have been made with respect to the requirements of the ship, the shipyard at which the ship will be constructed, and which design firms will be competing for the final design contract. Each decision made to date has had either a positive or a negative impact on the budget. For example, a decision to shed a capability can reduce the budget, while a decision to compress the schedule can increase the budget.

There are still many decisions that remain to be made at this stage of the JSS project. In constructing the cost estimation model, the PBO accounted for these uncertainties through a sensitivity analysis, and the resulting estimate varies significantly depending on the desired confidence level. The amount of uncertainty made it

prudent to present the results as a range—rather than a point estimate. This enables parliamentarians to better understand the potential implications of the decisions made and to be made.

Figure 3-1: Estimate Refinements as Decisions Are Made



Source: PBO

As more decisions are made and it becomes possible to further refine the model, this range of possible outcomes will shrink (see Figure 3-1). Once the requirements for the project are further solidified, possibly when the design is announced, there will be more detailed information with which to populate the model and reduce the sensitivity around certain variables. At such a time, if parliamentarians request it, the PBO can update the JSS cost estimate model. Depending on the level of data available, the PBO may be able to present a point estimate at an appropriate confidence level.

4 Appendix B: Costing Methods

The PBO adopted a parametric approach to assess the sufficiency of the budget allocation for this project. This decision was made by evaluating the benefits and risks of four widely-accepted methods.[45]

This is an overview of each of the four methods, discussing their appropriateness for this project.

Bottom-up Costing

Bottom-up costing (also called build-up or engineering build-up) involves estimating costs at the lowest definable level, then building a systems estimate by summing or "rolling up" detailed estimates for lower-level cost elements. Labour hours are multiplied by labour rates, and detailed parts and material costs are required—often down to the nut and bolt level.[46] The bottom-up method is used when there is detailed information at a low level about an item.

Bottom-up is complete: by developing an estimate at a low level, it is possible to show precisely what the estimate covers, ensuring nothing is overlooked. The high level of detail also provides a fairly accurate depiction of the actual process of producing the part or system. [47]

This approach was not feasible as the JSS is in too early in development to know what components or how many labour hours will be required.

Analogy

Costing by analogy involves comparing the cost of an item to a similar item. [48] An analogy can be done at the system, subsystem, or component level. In some cases, multiple analogies can be used at the lower WBS structure levels to build up to a higher level estimate.

Some adjustments are made to the cost of the old item, including programmatic information such as quantity or schedule; physical characteristics such as weight or materials; performance characteristics such as power or pointing accuracy; government or commercial practices; or contract type such as fixed price or cost plus. Costs are normalized for such things as exchange rates. Adjustment should be as objective as possible by identifying key cost drivers, determining how the old item is related to the new, and how the cost driver affects costs.[49]

Costing by analogy is usually appropriate early in the program life cycle when definition is lacking and a pre-existing cost model is unavailable. Analogy can also be used when there is insufficient data or program definition to develop a cost estimate using a more detailed technique. [50] To be accurate, the old system must be very similar to the new.

[45] These methodologies are also adopted by the Department of National Defence and documented in the department's *Costing Handbook* (2006).

[46] Cebok, Module 2.

[47] Cebok, Module 2.

[48] Cebok, Module 1.

[49] Cebok, Module 2.

[50] Cebok, Module 2.

In this instance, there are no close analogies; the differences between potentially comparable ships and the JSS are too significant. Further, comparators were constructed in different countries (some in more than one), at different points in time, under different conditions, complicating normalization.

Parametric

A parametric model is comprised of a number of cost estimating relationships (CERs). A CER is a mathematical relationship between cost and one or more technical, performance, or programmatic input.[51] CERs are derived from and tested against historical data.

The dependent variable is cost. The independent variable can be any number of inputs, otherwise known as "cost drivers". They are typically physical characteristics, performance or operational parameters, programmatic variables, or other costs. CERs are based on the assumption that the historical framework will remain relatively stable (e.g., the technology, manufacturing processes, etc., will not drastically change).[52]

Parametric models are versatile. They can be developed at any level given enough data. As design changes, effects to costs can be quickly and easily captured by varying inputs. They can be used in a wide variety of situations, from early planning to final contract negotiations.

Parametric models are relatively objective. CERs are derived from historical data and should only be used once they have been verified by statistical analysis as being good predictors of cost.[53]

In this instance, a parametric model was selected because the project is still in concept phase. As the design has not been selected and the specifications are not complete, there is insufficient data to undertake an engineering approach.

Expert Opinion

Expert opinion is the assessments of SMEs, corroborating or adjusting existing costs.[54] This technique is often seen as too subjective, but this concern can be mitigated if the expert's "opinion" is based on real data, which can be reviewed, and if the expert does not estimate outside the bounds of his experience. The use of multiple experts, with similar scopes of expertise, is also useful.

In this instance, expert opinion, without an underlying rationale, would not have been sufficiently objective from a budgetary perspective.[55] That said, the PBO regularly consults with SMEs to identify best practices for costing and develops all cost estimates using methodologies that observe the same regulations, policies, and procedures used by Government of Canada departments and agencies. While expert advice can inform a cost estimate, an estimate generated entirely on this method is difficult to validate and not reproducible. This would not be consistent with the level of analysis expected of the PBO.

[51] Cebok, Module 1.

[52] Cebok, Module 2.

[53] Cebok, Module 2.

[54] Cebok, Module 1.

[55] Cebok, Module 2.

5 Appendix C: JSS High Level Requirements

Table adapted from the JSS Statement of Requirement Version 5.5 (November 2009)[56]

Capability		Essential Requirement	Desirable Requirement
Cargo fuel	F76 (military diesel)	7,000 tonnes	
	F44 (military aviation kerosene)	980 tonnes	
Replenishment at sea (RAS)	Number of stations	4 (two stations per side)	+ astern refuelling station
Aviation	Number of helicopters	3	4
	Flight deck spots	1	2
Maximum sustained speed		20 kt[57]	22 kt
Survivability		DG NIXIE (torpedo decoy) CBRN (chemical, biological, radiological, and nuclear)	Acoustic/IR/RCS signature management Enhanced damage stability
Maneuverability		Bow thruster	
Ice capability		Ability to access Nanisivik Facility in summer navigation season Arctic shipping pollution Prevention regulations (ASPPR) type E	ASPPR type C can enter zone 6, while type E cannot
Operations functions	C4I (command, control, communications, computers, and intelligence)	Basic (current AOR 509)	Integrated/Networked
	Self defence	2 close-in weapon systems (CIWS) stand-alone electronic countermeasures (ECM) Defence against small boat threats (DASBT) mounts	CIWS ECM Electronic surveillance measures (ESM) DASBT integrated in Command and control system (CCS)
Accommodations		250 people	320 people
Medical		Role 2E (tactical medical evacuation)	
Cargo transfer systems	Containers	TEUs (twenty-foot equivalent unit)	Self-unloading alongside and at anchor
	Alongside jetty	Cranes	
	At anchor	Cranes and landing craft, vehicle, personnel (LCVP)	Landing craft utility (LCU)
Afloat JTFHQ		Space and weight only	Fitted for but not with (FFBNW) associated C4

[56] The Department of National Defence has approved Version 5.6 but no longer shares the document with outside parties. Government officials have indicated that small adjustments were made to the requirements, most notably to indicate that the essential requirements were subject to design to budget constraints.

[57] Knot (kt) is one nautical mile per hour.

6 Appendix D: Model Inputs

Level	Variable	Input	Explanation
System	Number of units	2	TruePlanning differentiates between costs associated with producing the prototype, or first ship in class, and costs associated with producing actual production units—those ships in class that follow the prototype unit. This distinction is made because the cost associated with producing the first ship in class is significantly higher than that of the production units that follow. Consistent with the Government's stated policy of building two JSSs with an option for a third, the inputs of the model have been set at one prototype and one or two production units.
SE/PM	Operating specification	1.60 Mobile (Water): Military Ships	The operating specification refers to the equipment's planned use (e.g. ground military, submarines, and air to air missiles). It has an impact on cost, as different operating specifications involve different requirements with respect to portability, reliability, structuring, testing, and documentation. TruePlanning attributes a value to each operating specification, and this value has a significant impact on development engineering costs. The default value assigned to military ships is 1.60 (midpoint of 1.4-1.8). This number reflects the additional testing and documentation requirements associated with military when compared to commercial ships.
	Multiple site development	2.5 Several locations: Two to three active locations within the same country. Poor communication	The multiple site development value describes communications challenges presented by teams operating in multiple geographic locations. Communication affects productivity and becomes more significant when development personnel work from different sites on the same equipment. This value is a function of the number of and quality of communication between the active locations for the program. In this case, there will be three active locations (i.e. the client (DND), the designer (TKMS or BMT), and Seaspan). Federal procurement rules put certain restrictions on the ability of contractors to communicate with federal employees. Since the Government must facilitate communication between the

			shipyard and the designer, delays or restrictions are likely. Where the communication between three active locations is characterized as poor, TruePlanning ascribes a value of 2.5.
	Vendor interface complexity	High	The vendor interface complexity describes the degree and intensity of requirements to interface with vendors or subcontractors on the project. It ranges from low to high. Technical reviews, audits, and quality assurance requirements in the context of this procurement will be significant as compared with non-military procurements. These requirements will be monitored through a series of "gates" or milestones used to track the progress of the project against its objectives. As such, vendor interface complexity will be high.
	Project complexity factor	75 High; Indicates planning and oversight levels typical in a mid-size to large or moderately complex project.	The project complexity factor is reflective of the planning and oversight activities necessary to successfully manage the project. The project complexity factor is used to predict the amount of the oversight and planning required to successfully manage the project. The value of this factor ranges from 0 to 200: a value of 0 will result in no planning and oversight calculations; a value of 50 results in the typical values for planning and oversight activities in a small to mid-size project; and, a value of 100 results in values typical for a large or highly complex project. A level of high was selected because of the complexity of managing a military procurement of a unique vessel requiring numerous audit functions and sign-offs.
	Number of vendors	1	Number of vendors indicates the number of outside sources that will be supplying equipment, software, or services. The value of this input influences the effort for system engineering activities. While the exact number of vendors that will be involved in this project is unknown, there will, at the very least, be one: Seaspan. As such, the number of vendors was set at 1. This is a conservative estimate.

Acquisition	Start date	3/1/2014	This date is taken from the most recent Report on Plans and Priorities (RPP).
	Weight of structure	18,469,520 lbs	The weight of structure indicates the weight of the mechanical/structural portion of the equipment. As weight increases, the amount of effort associated with engineering increases, tempered by the impact of increased or decreased technological maturity. Weight increases are also result of increases in effort and material required for prototype development.
	Manufacturing complexity of structure	3.78	The MCPLXS represents a technology index for the structural portion of the equipment and is linked to the operating specification. MCPLXS is a measure of the equipment's technology, its producibility (material machining and assembly tolerances, machining difficulty, surface finish, etc.), and yield. The value for MCPLXS should be determined either through calibration using historical data from past projects or through one of the tools available in True H to guide the user to the right value. In this case, the PBO calibrated using historical data on the Protecteur-class AOR. The MCPLXS returned by that calibration was 3.78.
	Percent of new structure	85%	The percent of new structure represents the amount of new structural design effort based on design tasks which already exist or may have already been completed. The value for the percent of new structure is a cost driver for the development engineering activity for the equipment. The model assumes that new structure requires full development engineering activity and that existing structure requires no engineering at the component level. Expert opinion suggests that such design effort will be required whether or not the JSS is based on a pre-existing ship. The adaptation of a pre-existing design to respond to Canadian requirements would involve a significant amount of redesign work.
	Percent design repeat for structure	40%	This input captures the repeated use of design components reflecting the symmetry of the ship's hull. Percent of design repeat is determined by the ratio of redundant hardware to unique hardware. A completely symmetrical

			ship would result in 50% design repeat. Although the hull itself is symmetrical, some internal components are not, hence a value of less than 50% repeat.
	Engineering complexity	1.1 New design, within the established product line, continuation of existing state of art. Mixed experience, some are familiar with this type of design, others are new to the job.	The engineering complexity value represents a measure of the complicating factors of the design effort as they relate to the experience and qualifications of the engineering design team. Engineering complexity is a significant driver in the development engineering effort. As skill set and experience decrease or as the engineering challenges increase, the costs for development engineering increase. Development manufacturing and development tooling and test activities also increase with increasing complexity as the engineers and assemblers grapple with implementing and testing prototypes designed by less experienced personnel or within less than ideal design conditions. Whether the Government settles on an adapted version of the Berlin-class or clean-sheet design by BMT, the JSS will constitute a new design. Engineering complexity has been returned on this basis, but while making allowances suggesting that the equipment will be part of an “established product line” and a “continuation of existing state of art.” Seaspan's experience has been in the field of barges, ferries, smaller commercial ships. The company has very little experience in the class of ships that will be produced. As such, engineering complexity has further been described as “mixed experience” with some of the team being “familiar with this type of design”. The PBO is of the view that, based on expert opinion, such assumptions are conservative (i.e. they will return a lower cost estimate). Engineering complexity has no impact on production costs, but does have a non-linear impact on development costs. A 10% increase in engineering complexity will have greater than a 10% increase on development costs.

	Development engineering	Start: 03/01/2014 End: 4/30/2018	These dates are taken from the RPP.[58]
	Production manufacturing	End: 09/30/2019	This date is taken from the RPP.[59]
Other	Labour rates	As per PRICE model	TruePlanning contains pre-existing labour unit costs for Canadian production. These figures are consistent with data available from the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC and relevant collective agreements.

[58] See Appendix E: Current Project Schedule.

[59] *Ibid.*

7 Appendix E: Current Project Schedule

Table 7-1: Major Milestones

List of Major Milestones	Date
Options Analysis	Fall 2009
Revised Project Approval (Definition)	June 2010
Project Definition Phase Recommenced	July 2010
Project Approval (Implementation)	February 2014
Award of Implementation Contract	March 2014
Initial Operating Capability - First Ship	Spring 2018
Final Operating Capability	Fall 2019

Source: Treasury Board of Canada Secretariat, 2012-2013 Reports on Plans and Priorities: National Defence: Supplementary Tables (2012), online: Treasury Board of Canada Secretariat <http://tbs-sct.gc.ca/rpp/2012-2013/inst/dnd/st-ts04-eng.asp#jss-nsi>.

8 Appendix F: List of Replenishment Vessels

Table 8-1: List of Replenishment Vessels

Ship	Navy	Type of ship	Status	Year	Size (tonnes full)
Cantabria	Spain	Fleet Replenishment Ship	In service	Cantabria Laid down[60] 2007 Launched[61] 2008 Delivered July 2010	19,500
Patino	Spain	Fleet Logistic Tanker	In service	Patino Laid down 1993 Launched June 1994 Commissioned[62] June 1995	17,045
Berlin	Germany	Fleet Logistic Tanker	In service	Berlin Launched April 1999 Commissioned April 2001 Frankfurt AM Main Launched Jan 2001 Commissioned May 2002 Bonn Due to enter service late 2012	20,240
Karel Doorman (JSS)	Netherlands	Joint Support Ship	Laid down Commission date TBD	Laid down June 2011	27,000
Amsterdam	Netherlands	Fast Combat Support Ship	In service	Laid down May 1992 Launched Sep 1993 Commissioned Sep 1995	17,040
Lewis & Clark	USA	T-AKE Dry Cargo and Ammunition Ship	In service	T-AKE-1 Launched 2005 T-AKE-2 Launched 2006 T-AKE-3 Launched 2006	40,298

[60] Laid down: The term *laid down* was originally used to mark the beginning of construction on a ship's keel. Since many modern ships are now constructed in modules, the term *laid down* is now more generally used to mark the beginning of the construction of a ship.

[61] Launched: Once the hull of a ship is completed, it may be *launched* from the shipyard into the water.

[62] Commissioned: A ship is *commissioned* when it is deemed ready for service.

Ship	Navy	Type of ship	Status	Year	Size (tonnes full)
				T-AKE-4 Launched 2007 T-AKE-5 Launched 2008 T-AKE-6 Launched 2008 T-AKE-7 Launched 2008 T-AKE-8 Launched 2009 T-AKE-9 Launched 2009 T-AKE-10 Launched 2010 T-AKE-11 Launched 2010 T-AKE-12 Launched 2011 T-AKE-13 Due for launch 2013 T-AKE-14 Due for launch 2014	
Henry J. Kaiser	USA	Oiler	In service	T-AO 187 Laid down 1984, Commissioned 1986 T-AO 188 Laid down 1984, Commissioned 1987 Decommissioned 1996 T-AO 189 Laid down 1985, Commissioned 1987 T-AO 190 Commissioned 1987 Decommissioned 1996 T-AO 191 Commissioned 1991 Decommissioned 1997 T-AO 192 Commissioned 1992 Decommissioned 1998 T-AO 193 Laid down 1986, Commissioned 1988 T-AO 194 Laid down 1989, Commissioned 1991 T-AO 195 Laid down 1987, Commissioned 1989 T-AO 196 Laid down 1989, Commissioned 1991 T-AO 197 Laid down 1988, Commissioned 1990 T-AO 198, Laid down 1989, Commissioned 1992 T-AO 199, Laid down 1990,	42000 (42,667.8 long tonnes)

Ship	Navy	Type of ship	Status	Year	Size (tonnes full)
				Commissioned 1993 T-AO 200, Laid down 1990, Commissioned 1992 T-AO 201, Laid down 1991, Commissioned 1995 T-AO 202, Laid down 1991, Commissioned 1993 T-AO 203, Laid down 1994, Commissioned 1996 T-AO 204, Laid down 1992, Commissioned 1995	
Wave	UK	Auxiliary oiler	In service	Wave Knight Laid down October 1998 Launched September 2000 Commissioned April 2003 Wave Ruler Laid down February 2000 Launched February 2001 Commissioned April 2003	
MARS	UK	Fleet tanker	Planned	Due into service 2016	
Durance	France	Underway replenishment tanker	In service	Meuse (A607) Laid down 1977 Commissioned 1980 Var (A608) Laid down 1979 Commissioned 1983 Marne (A630) Laid down 1982 Commissioned 1987 Somme (A631) Laid down 1985 Commisioned 1990	(A607) 17,900 All variants 18,500
Durance (Success)	Australia	Underway replenishment tanker	In service	Laid down 1980 Launched 1984 Commissioned 1985	17,933
HMAS Sirius	Australia	Replenishment tanker	In service	Launched 2004 Commissioned 2006	37,000 tonnes (deadweight)

9 Appendix G: Risks Used to Develop Confidence Level

This table provides a summary of the parameters used to generate the confidence level for the JSS estimate. An explanation of the optimistic and pessimistic boundaries of these ranges is provided in the table.

Table 9-1: Range of Input Variables

Variable	Optimistic	Pessimistic	Explanation of Range
Weight of structure	18,469,520 lbs	22,833,440 lbs	It is not possible to predict, with any accuracy, the weight of the ship so early in the design process. However, based on the requirements of the Department of National Defence, the PBO adopted a range reflective of the high and low values of ships of comparable capacity. The PBO adopted the weight of the Protecteur-class as the optimistic (lightest ship) value and then Berlin-class (heaviest ship) as the pessimistic value.
Manufacturing complexity for structure	3.39	4.25	In order to establish the boundaries for the MCPLXS, the PBO ran the calibration of comparable ships (see Table 2-5). This analysis returned values ranging from 3.39 (corresponding to the Henry J. Kaiser) to 4.25 (corresponding to the Wave).
Percent of new structure	50%	85%	It is not possible to predict the percent of new structure of the ship until a significant portion of the design decisions have been made. However, based on the experience of SMEs, the PBO determined that an acceptable range would be from 50% to 85%. A discussion of the sensitivity of this variable is provided in the methodology section of this report.
Percent of design repeat for structure	50%	20%	It is not possible to predict percent of new structure of ship until a significant portion of design decisions have been made. Assuming perfect symmetry, it is impossible to have a value greater than 50%. Based on historical naval programs, it is unlikely to have a value of less than 20%.
Engineering complexity	0.9	1.1	This variable is calculated by the TruePlanning application. It is based on a combination of the technology being used in the construction of the ship and the experience of those involved in the design process. The input for the technology is fixed as the JSS will be a new design leveraging existing technology. Based on the current capacity of the designers and the shipyard, the experience levels selected for the model is mixed experience. However, if the designers and the shipyard are able to procure more experienced professionals, the process may be optimized. The optimistic value of 0.9 is based on a scenario where experience designers can be obtained.

10 Appendix H: Defence Price Escalation

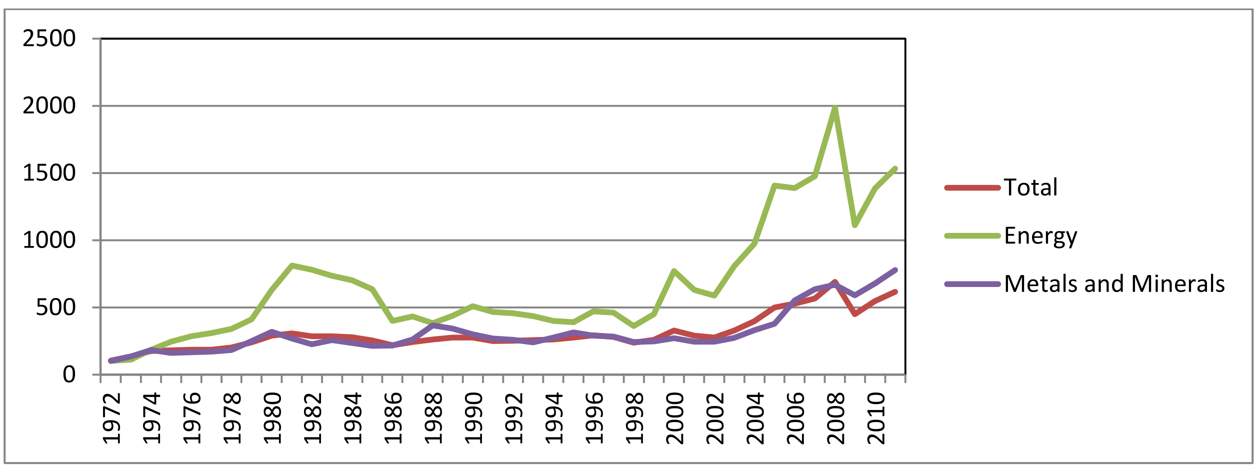
Traditional inflation indexes are not well suited to the defence budgeting process because non-market factors drive defence price escalation.

The Department of National Defence (DND) often procures items that are complex in nature, have unique requirements, and for which there are a limited number of providers. Consequently, many acquisitions, such as the JSS, are multi-year projects.

Allocating and managing the budgets of multi-year projects requires an adjustment for changes in the costs of goods and services over the lifetime of the project. Generically, the term "inflation" is used to describe escalations in cost over time. However, the year-over-year escalation in the cost of defence acquisitions can significantly exceed that of the common inflation indexes because true inflation is only one factor contributing to the cost escalation observed in defence procurements.

The most common measure of inflation—the consumer price index (CPI)—is calculated by measuring the changes in the cost of a basket of consumer goods and services. Although individual goods and services fluctuate at differing rates, CPI has remained relatively stable in recent years at around 2%.[63] However, CPI it is not an accurate measure of the cost escalation in the defence industry, as the weighted basket of goods and services used to calculate CPI is not representative of the inputs required to build military equipment.[64] While core CPI is weighted towards household items, the chief inputs for defence equipment are materials (minerals and energy) and labour. Since the increase in the cost of energy has on average exceeded 2% per year,[65] it follows that defence price escalation can be expected to exceed CPI by some measure.

Figure 10-1: Bank of Canada Inflation Indexes



Source: Bank of Canada

[63] Bank of Canada, *Consumer Price Index, 2000 to Present* (2012) online: Bank of Canada <http://www.bankofcanada.ca/rates/price-indexes/cpi/>.

[64] David Kirkpatrick, "Is Defence Inflation Really as High as Claimed?" (October 2008) RUSI Defence Systems 66 at 71.

[65] Bank of Canada, *Inflation* (2012) online: Bank of Canada <http://www.bankofcanada.ca/monetary-policy-introduction/inflation/>.

An alternate method of accounting for the increase in cost over time is the Gross Domestic Product (GDP) deflator. Like CPI, GDP is not representative of the inputs for military procurement. For example, “machinery and equipment” represents approximately 20% of defence spending, but only 8% of GDP.[66] Moreover, defence acquisitions are susceptible to exchange rate fluctuations that are not captured by GDP.[67]

Non-Market Factors Contributing to Defence Price Escalation

Based on the arguments above, it would seem that the logical conclusion would be to create a defence-specific index based on a representative basket of goods, with an appropriate adjustment for fluctuations in exchange rates. However, data on defence procurements have demonstrated a trend that exceeds what can be explained by price indexes alone.[68]

In 2006, the RAND Corporation found that escalation in the naval shipbuilding industry over a 50-year period was between 7 and 11% per year depending on the class of vessel.[69] RAND and other defence economists who have studied this trend have identified two significant non-market factors contributing to this additional escalation: 1) the dynamics of the consumer-supplier relationship; and 2) consumer behaviour.[70]

There are few buyers and few suppliers of defence equipment. Many defence procurements, including those of naval ships, require some part or all of the acquisition to be customized, resulting in unique product for which there is only one customer. This relationship, described by economist as a monopsony-oligopoly,[71] results in the consumer paying a premium for goods as the supplier must ensure it is able to recoup its cost and make a profit on a product that has no other potential consumer.

In addition to the premium resulting from the consumer-supplier relationship, there are additional costs incurred as a result of the business processes of departments of defence. The RAND Corporation found that the US Navy, as a customer, had contributed to cost escalation through the use of military standards,[72] increased technological expectation,[73] and ongoing redesign requirements.[74]

Implications for the JSS Project

The budget envelope for the JSS project was announced in “budget year dollars”, meaning that no adjustment will be made to the budget to reflect inflation—defence-specific or otherwise. Figure 10-2 shows how the $2.6 billion budget has decreased in real terms since the 2010 announcement of the JSS project. Thus, when the JSS

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[66] Binyam Solomon, “Defence Specific Inflation: a Canadian Perspective” (2003) 14 Defence and Peace Economics 19 at 23.

[67] *Ibid*.

[68] David Kirkpatrick, *supra* note 64.

[69] Mark Arena et al, *supra* note 35.

[70] *Ibid* at 8; Binyam Solomon, *supra* note 66.

[71] A monopsony-oligopoly occurs when there is one buyer and few sellers.

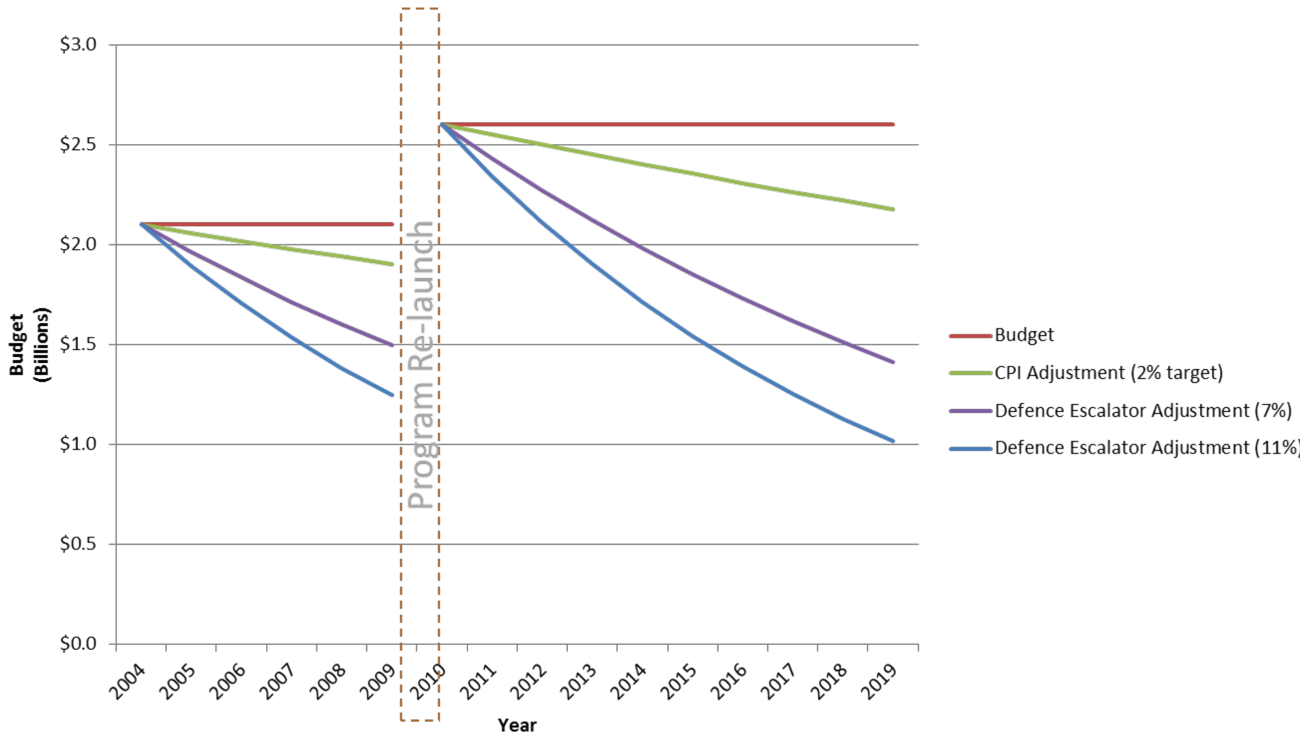
[72] Mark Arena et al, *supra* note 35 at 42.

[73] *Ibid* at 11.

[74] *Ibid.*

Project was re-launched with a new budget of $2.6 billion ($500 million increase over the original project budget), the actual project budget was effectively decreased.

Figure 10-2: Budget Discounted for Naval Escalation Factors



Source: PBO

11 Annex A: Capacity Analysis of the Vancouver Shipyards (Seaspan)

Capacity Analysis of the Vancouver Shipyards

(SEASPAN)

Prepared for the

Parliamentary Budget Officer

George Petrolekas and David Perry

Introduction

In October 2011, the Government announced that Irving Shipbuilding Inc. had been selected for the combat work package and Seaspan/Vancouver Shipyards for the non-combat work package of the National Shipbuilding Procurement Strategy. In February 2012, the Government signed umbrella agreements with the two companies.

In winning the contract for the large non-combat vessels Seaspan will be responsible for building one class of ship for DND and three for Fisheries and Oceans Canada/Canadian Coast Guard for an expected total of seven ships:

- 2 (with the option of one additional) Joint Support Ships (JSS);
- 1 Offshore Oceanographic Science Vessel;
- 3 Offshore Fisheries Science Vessels; and
- 1 Polar Icebreaker.

On July 10, 2012 the Government announced the signing of a preliminary contract of $9.3 million with Irving to enable the company to "review the existing Canadian-developed Arctic Offshore Patrol Ships design and specifications, prepare an execution strategy, and deliver a proposal detailing the scope and cost of the subsequent definition contract." The definition contract would "complete the Arctic Offshore Patrol Ships design to production-level drawings" and would be followed by an implementation contract to build and deliver the ships. As of November 2012, the Government has not yet signed any such contract with Seaspan related to the JSS program. However, the Government has signed an ancillary contract with Seaspan to solicit their input into the ship design to avoid receiving a finished design that is difficult or costly to build.

Seaspan

Seaspan is an association of Canadian companies involved in coastal marine transport, marine services, ship repair and shipbuilding created through a series of acquisitions and mergers in British Columbia over the past 40 years. Seaspan presently comprises Seaspan Marine (coastal marine transport and shipdocking services), Seaspan Ferries (commercial Roll-on, Roll-off [RO-RO] large ferry services), Seaspan Shipyards (which includes the Vancouver Drydock, the Vancouver Shipyards and the Victoria Shipyards) and Marine Petrobulk (which provides fuel services to vessels entering the ports of Vancouver, New Westminster, Victoria, Prince Rupert, Kitimat and Nanaimo).

The original Seaspan Marine Corporation was created in 1970 by the merger of two prominent coastal towing firms: Vancouver Tug Boat Company and Island Tug & Barge. In addition to being the largest tug and barge operation on the Pacific Coast, Vancouver Tug Boat Company also owned Vancouver Shipyards.

Vancouver Shipyard was founded in 1902, and served primarily as a builder of small fishing and pleasure boats, although the company built two minesweepers for the Royal Canadian Navy during the Second World War. Since that time, the company has constructed, outfitted or converted 170 tugs, barges and ferries at the shipyard.

Seaspan acquired many of the assets of the former Versatile Pacific Shipyards in two separate transactions. First, Seaspan and Allied Shipbuilders formed a partnership and, with assistance from both Federal and

Provincial governments, created Vancouver Drydock Company to acquire the firm's floating drydocks and some onshore facilities in North Vancouver once the company became defunct. Seaspan later acquired its partner's interest in the company.

In 1994, Vancouver Shipyards (Esquimalt) Ltd. (now Victoria Shipyards) was created at the Esquimalt Graving Dock after acquiring the assets of the former Yarrows shipyard, once the latter firm became insolvent. Since then, Victoria Shipyards has become prominent in refitting and repairing cruise ships and Royal Canadian Navy vessels. Victoria Shipyard's work includes life-extension servicing of the five Halifax class frigates based at CFB Esquimalt in addition to serving as the shipyard facility for in-service support of the Victoria Class submarines. Victoria Shipyard also built the Orca class Patrol Craft Training (PCT) vessels for the Royal Canadian Navy, constructed over two dozen search and rescue lifeboats for the Canadian Coast Guard, in addition to their work on small coastal ferries.

Timeline of notable corporate events:

- 1996—Dennis Washington of Montana and his Washington Group of companies purchases Seaspan.
- 1998—Washington purchases the rail and truck ferry service of Coastal Marine Operations from the Canadian Pacific Railway, turning it into a subsidiary of Seaspan and renaming it Seaspan Coastal Intermodal.
- 1999—Seaspan, Cates, Seaforth, Norsk and Kingcome are all amalgamated into Seaspan International. Dennis Washington sets up Washington Marine Group with separate divisions for towing, shipbuilding and ship repair, coastal intermodal and bunkering services.
- 2010—Vancouver Shipyards is shortlisted for the Government of Canada's National Shipbuilding Procurement Strategy (NSPS). The NSPS program, worth $35 billion, will build replacement ships for the Royal Canadian Navy and the Canadian Coast Guard over a 30-year period. Two work packages, one to build combat vessels, the other non-combat vessels, were competed. Seaspan bids on both packages.
- 2011—In a corporate restructuring, Washington Marine Group is renamed Seaspan Marine Corporation; the shipbuilding, coastal ferries and bunkering services become subsidiaries of the towing division.
- 2011—As the winning bidder of the $8 billion non-combat package on 19 October 2011, Seaspan Marine will build 7 and possibly 8 vessels for the Canadian Coast Guard and Department of National Defence.

Build In Canada and Its Implications for the Shipyard

The NSPS process dictated that the ships built under its framework be 'built' in Canada. Specifically, this means that "metal fabrication of the hull, the decks, the superstructure, the mast(s), and any modules making up the foregoing items, whether completed, unassembled, disassembled, unfinished or incomplete, will be conducted in a facility in Canada, and that the vessel will be assembled in Canada."[75] However, it should be noted that

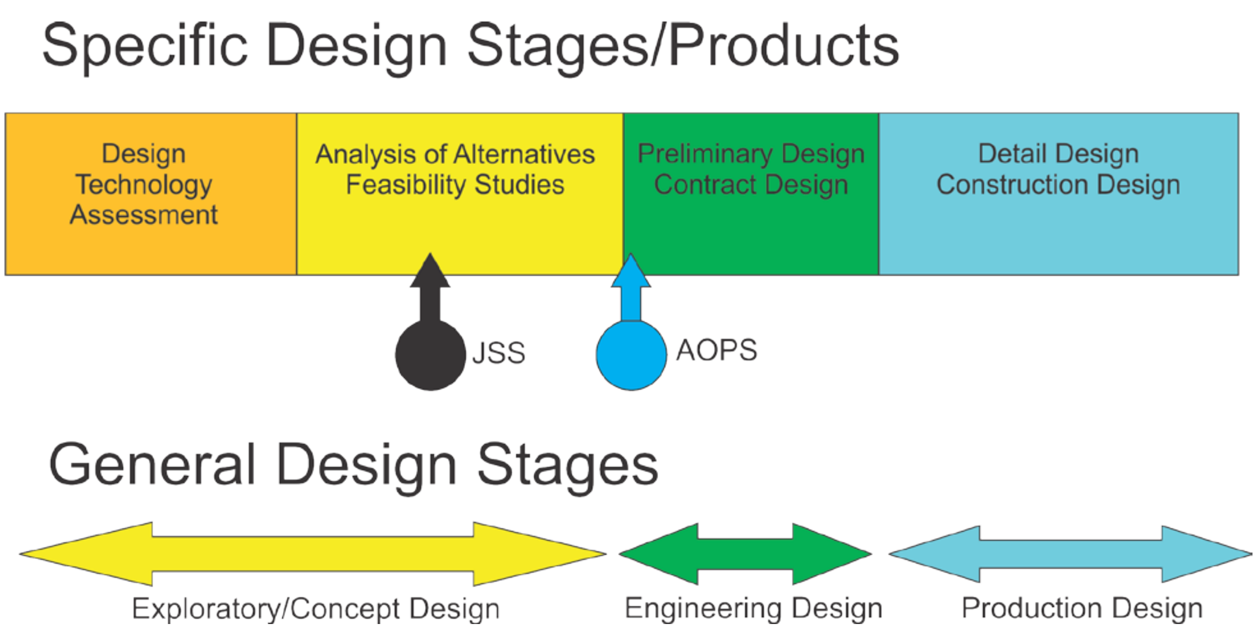
[75] Canada. NSPS Bid Certificate F (7 February 2011) Solicitation No. EN578-111588/B.

"ship construction" itself accounts for only 35-50% of the cost of a low to medium complexity ship.[76] The systems, software, ancillary components, sensors and weaponry that will complete the ship represent the remainder of the ship's contract value. Subcontracts for the remaining components of the vessels and their associated Industrial and Regional Benefits (IRBs) may actually represent the most significant cost dimensions of the project. However, the manner in which sub-systems will be sourced is not known.

Naval Shipbuilding Templates

Naval ship design is a complex process. A naval ship is an ecosystem in its own right. The primary function for many ships is to serve as a platform for the weapons systems. In the case of a Replenishment Oiler (AOR) its primary function is to serve as a distribution system for food, fuel and ammunition for the fleet, yet as a naval ship also having onboard the accompanying sensor systems, defensive weaponry and command and communications systems. It must also sustain crews for extended periods of time which means that the design must account for a number of 'hotel' features, including among others, accommodations, messing, heating and ventilation, etc. Finally, there are several design factors that account for basic operating conditions, such as operations in specified sea states and environmental conditions. These factors include hull forms, human factors, mission systems, and propulsion, amongst others.

Figure 11-1: General Activity Flow of Ship Design Stages



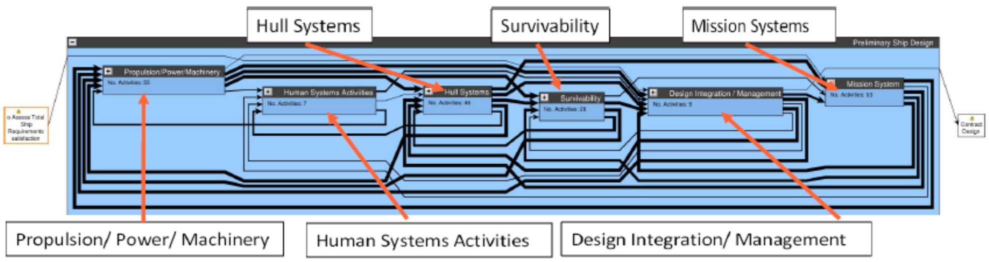
Source: Naval Surface Warfare Center, The Navy Ship Design Process, (June 1, 2012), online: Naval Sea Systems Command. <http://www.navsea.navy.mil/nswc/carderock/docs/4368_Ship_Design_Process_B_Section_A.pdf>.

Ships therefore are unique platforms, generally built in small volumes, and highly specialized in function. In contrast to other military platforms such as tanks or aircraft with their much higher volume of production, ships generally benefit from production line efficiency improvements to a much lower extent than other platforms.

[76] CADSI Marine Studies Working Group, *Sovereignty, Security and Prosperity*. (May 2009), online: CADSI <http://www.defenceandsecurity.ca/UserFiles/File/pubs/cadsi-mir.pdf>.

These unique characteristics of design, function and production mean that ships are built on a completely different template than other military materiel.

Figure 11-2: Interrelationship Systems



Shown is the expanded view of Preliminary Design. Preliminary Design is made up of six general Design Areas:

1. Hull Systems	to	"Float"
2. Mission Systems	to	"Fight"
3. Propulsion/ Power /Machinery	to	"Move"
4. Human Systems	to	"Enable"
5. Survivability	to	"Survive"
6. Design Integration & Management	to	"Integrate"

Interactions are needed between the Design Areas, with iterations and trade-offs required to converge to a baseline.

Source: Naval Surface Warfare Center, The Navy Ship Design Process, (June 1, 2012), online: Naval Sea Systems Command. <http://www.navsea.navy.mil/nswc/carderock/docs/4368_Ship_Design_Process_B_Section_A.pdf>.

Interrelationship of various systems which are designed separately but which must eventually be integrated for efficient function within the ecosystem. In the design phase, successful integration of separate systems is critical to controlling subsequent costs.

Systems Integration in the Design Phase and Production Phases — A Simplified Guide

Systems integration on ships (and other military land and air vehicles) is a complex and time consuming effort and usually represents a large part of the costs associated with the final product. There are two major phases of integration. The first occurs in the design phase where systems and their interfaces are designed with automation and cross-platform operation in mind. The second integration effort occurs during the building phase where these systems are installed and then tested to ensure that they work as specified. Often times, initial physical integration work is done in a laboratory environment to ensure function before final fitting out onboard a ship.

The systems shown in Figure 11-2 all have sensors that produce information on different aspects of a ship's operation. Some of this information is shared across systems. For example, location data (with respect to the ship's position) is relevant information to the ship's safe navigation, as well as for survivability systems (such as the operation of distress signals) and is absolutely necessary for the targeting data provided to weapons systems.

Equally, heating, ventilation and air conditioning (HVAC) systems are connected to damage control systems and are needed for the efficient operation of machinery, in addition to their important role in providing crew comfort and survivability. For example, temperature sensors will provide information on whether machinery is operating to specification and will indicate problem areas, and the HVAC system becomes involved in controlling and containing damage by shutting off or rerouting air conduits, and contributing information to damage control systems. Other systems monitor the flow of liquids such as fuel and water and dry goods such

as cargo and continually rebalance the storage of these across the ship to maintain proper ballast/balance arrangements which contribute to sea keeping. These are by no means exhaustive examples but serve to illustrate the interrelationship between a ship's many systems.

At some point, all these various systems converge to a point of human/machine interface. Without integration, completely separate systems (networks) would be needed to monitor and manage the various components of a ship's operation shown in Figure 11-2. On a bridge, this would manifest itself in entirely separate monitors and information for each system, and would require that operators correlate diverse information before undertaking separate actions to manage each system separately. This contributes not only to the potential for information overload, but could also increase manpower requirements.

In the design phase, engineers strive to unify data from separate systems as much as possible into a unified presentation of information to simplify human tasks and understanding at the human/machine interface. In practice, this is a complex and difficult engineering challenge. In the case of a warship, integration is not simply the integration of systems that manage the physical operation of the ship itself, but also the integration of sensors and weapons that permit a warship to defend or to attack.

Situational awareness is required for 360 degrees in three dimensions in widely differing environments: sub-surface, surface and air. This requires that data inputs from differing sensor types (radar, sonar, electronic intercept, and other detectors) often using different data interfaces be integrated for situational awareness and then be converted into vastly differing targeting information, sometimes requiring specific environmental information, which can then be conveyed to a weapons platform.

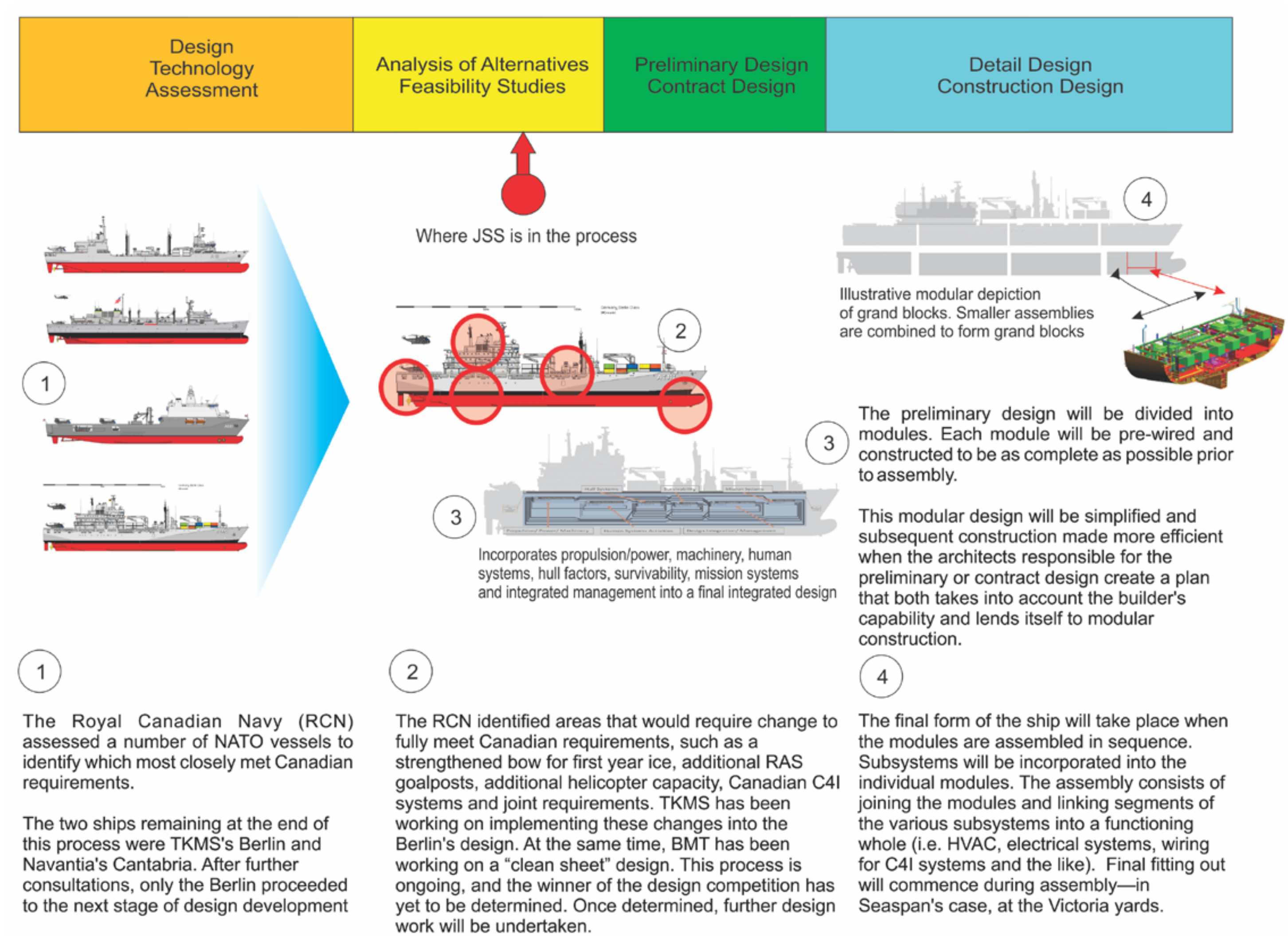
Further complicating the task for integrators is that most warship systems, unlike their civilian counterparts, must have system redundancy. Systems could be damaged in a manner that would affect their operations, an engineering challenge that civilian ships do not normally anticipate. As a result, the requirement for systems integration in warships is substantially higher, given the need to integrate multiple redundancies.

Warships must be designed on the assumption that many of the separate systems come from different manufacturers and use different management systems and computer languages to convey information. In most cases however, industry standards exist that facilitate the integration. For example, GPS location data largely conforms to a common standard, so GPS based systems, whether navigational, safety or weapons, are able to use common data. The design architecture and subsequent integration task is to provide linkages across platforms through data busses and software which permits migration of data across platforms and eventually present these linkages at the human/machine interface in useable form. If a common standard data language is present, then mitigation software needs to be written to translate differing inputs into a common use system.

The architecture of integrated systems during the design phase remains "conceptual" until the actual build phase.

As an appropriate analogy, a telecoms network with all its cabling, switches, routers and terminals can be designed and built to a certain specification or function. Notwithstanding that, it is not until production integration occurs that the function of these systems becomes apparent in real life.

Figure 11-3: Shipbuilding Design and Build Process



Design/Build Model

There are three templates that states generally follow for the construction of their naval fleets with respect to the allocation of design and shipbuilding roles. While variations exist depending on a nation's circumstances and fiscal aims, these general templates are: i) a "fully integrated" design/build approach; ii) a "hybrid" approach that sees portions of the overall build split off from the company responsible for design; and iii) a "separate" design/build process.

By following the third approach, the Joint Support Ship project departs both from previous Canadian naval shipbuilding practices, and international standards as practiced by notable shipbuilding nations such as the United States, France and Spain. Under the current Canadian process, the JSS design is being developed independently of the shipyard that will actually build it. Two designs are currently under consideration. In March 2012, the government awarded contracts to TKMS, to produce an adapted design based on its *Berlin* class vessel. A second design contract was awarded to the UK/Canadian engineering firm BMT Fleet Technology to provide a customized JSS design generally described as the "clean sheet" design. Notably, while BMT Fleet Technology specializes in marine engineering and naval architecture, TKMS by contrast both designs and builds naval vessels, and is one of the largest manufacturers of naval vessels for export.[77] The BMT design is essentially a purpose-built, Canadian-unique design; the TKMS design, if adapted to the Canadian statement of operational requirements, will likely be significantly different than the Berlin class.

After initial designs are completed, they will be passed to the Seaspan shipyard for a validation that will include an assessment of their prospective costs to ensure that "the final designs are efficient and affordable."[78] Subsequent to that evaluation, the shipyard itself will be awarded two separate contracts to advance the work on the design before construction will start. This will begin with an ancillary contract to allow the yard to better understand the requirement and selected design. This will be followed by a production or construction engineering contract to evolve the design to production level drawings, before a contract for the actual construction is signed.[79] In essence, this is the breakdown of the engineering design to blueprints that will guide the production and sequence of the module construction, assembly and subsequent fitting out. It should be underscored that there is some risk that the ship will require re-design work if the shipyard encounters obstacles or increased costs to build the ship if the design is not optimized to the shipyard's capabilities.

This process represents a departure from past practices with Canadian naval shipbuilding programs that have normally awarded both the design and shipbuilding contracts to the same firm. For example, Saint John Shipbuilding Limited was initially awarded a contract for both the design and build of six frigates for the Canadian Patrol Frigate program. While the contract was subsequently amended to have three frigates built at a different shipyard and the overall order was increased to a total of twelve, Irving was ultimately responsible for "designing, developing, producing and delivering 12 fully-supported frigates within a ceiling price of $6.2B

[77] BMT Fleet Technology, "Services." (2012), online: BMT, <http://www.bmtfleet.com/?/1739>; ThyssenKrupp Marine Systems, "Products & Services." (8 November 2012), online: ThyssenKrupp <https://www.thyssenkrupp-marinesystems.com/index_en.php?level=1&CatID=3&inhalt_id=3>; John Birkler, et al., *Differences Between Military and Commercial Shipbuilding* (2005), online: RAND Corporation <http://www.rand.org/pubs/monographs/2005/RAND_MG236.pdf>.

[78] Ken Bowering, "National Shipbuilding" (2012) 8 *Canadian Naval Review* at 19-23.

[79] Public Works and Government Services Canada, *Backgrounder: NSPS Update – October 2012,* (18 October, 2012), online: Public Works and Government Services Canada <http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/fiche-backgrounder-eng.html>.

(BY$)."[80] The project to develop a coastal defence capability in the 1990's similarly combined the design and build. A $650 million contract for both the design and build of 12 vessels was awarded to SNC Lavalin.[81]

This "Fully Integrated" design/build approach is the most commonly employed method of building large naval vessels internationally, although it can take different forms. In the United States especially, military shipbuilders have become "high-technology defence production firms,"[82] that combine shipyard facilities with systems integration and other high-technology elements. Thus, the American defence conglomerates Northup Grumman, Lockheed Martin and General Dynamics are each major naval shipbuilders that engage in both design and construction, and often systems integration. For example, the US Navy's Littoral Combat Ship (LCS) program involves two separate contracts for the design and build of unique variants of the LCS by Lockheed Martin and General Dynamics.[83]

The Spanish shipbuilder Navantia, the fifth largest in Europe, is one of the very few companies that has a full spectrum capacity in the fields of design, development, production, integration, propulsion and naval combat systems as well as the ability to deliver fully-operational vessels. Fully owned by the Spanish state through an arm's length commercial corporation (SEPI- similar to a Canadian Crown Corporation), Spain also follows this fully integrated approach to the design, build and support of naval ships. Unlike the privately owned U.S. model, and the state-owned Spanish model, France's DCNS provides an example of a private/public partnership (65% publically owned/35% by Thales), which nevertheless provides full spectrum and integrated services to the French Navy.

An alternative to this model are shipbuilders that have adopted the approach of becoming more generalized heavy industrial firms, such as ThyssenKrupp in Germany that specialize in a number of wider industrial production efforts in addition to building military and commercial vessels. Finally, more specialized facilities also exist to conduct both design and build work on specialized ship types. These specialized facilities include Newport News Shipbuilding, which has sole responsibility for US Naval Aircraft Carriers and General Dynamics Electric Boat division which is the sole contractor for U.S. submarines. [84] The common thread throughout these approaches is that a single corporate entity is responsible for both design and construction, and in most cases the life-cycle or in-service support.

Other shipbuilding models have retained a combined design/build model with a consortium approach to shipbuilding. For example, the UK's project to acquire its Type 45 destroyer saw BVT receive a contract for the design and build of the ship, with MDBA contracted directly for the weapons system.[85] Similarly, the scale of the design and construction tasks involved in the UK's aircraft carrier program saw the Ministry of Defence form an "Aircraft Carrier Alliance" with the main industrial partners BAE Systems, Thales, and Babcock

[80] Chief Review Services, *Interdepartmental Review of the Canadian Patrol Frigate Project*. (26 March 1999), online: DND/PWGSC <http://www.crs-csex.forces.gc.ca/reports-rapports/pdf/1999/framework-cadre-eng.pdf> at 22.

[81] CADSI Marine Studies Working Group, *supra* note 76 at 10.

[82] John Birkler, et al. *supra* note 77 at 52.

[83] Ronald O'Rourke, *Navy Littoral Combat Ship (LCS) Program*, (Washington: Congressional Research Service, 6 April 2012).

[84] Newport News Shipbuilding, *US Navy Aircraft Carriers* (2012), online: Newport News Shipbuilding <http://nns.huntingtoningalls.com/products/carriers/index>.

[85] National Audit Office, *Ministry of Defence: Providing Anti-Air Warfare Capability* (13 March 2009), online: National Audit Office <http://www.nao.org.uk/publications/0809/the_type_45_destroyer.aspx>.

Marine.[86] While six shipyards are involved in ship construction, the alliance collectively was responsible for both the design and build. However, this is reflective of a trend in the UK where the United Kingdom is consolidating the remaining private shipbuilders into a single entity operating with a strategic agreement with the Ministry of Defence. Similar consolidation was done with the aerospace industry decades earlier.

Australia uses a model where it contracts both the design and build to fully integrated shipyards for work where there is domestic capacity. Offshore contracting exists for vessels whose construction is beyond the abilities of the domestic shipbuilding industry. In the early 1980s, dockyards were publically owned and operated, primarily to repair and maintain foreign-built naval vessels. In the 1990's, the government privatized its shipbuilding infrastructure holdings, triggered in part by the decision to build future frigates and Collins Bay submarines in Australia, which was seen as a means of facilitating a viable domestic shipbuilding industry. Some ships and submarines have been based on foreign designs (for example, the Collins Bay is a modified Swedish design). However the detailed engineering and production engineering have been performed by the same firms which will build the ships. By exception, Australia contracts for specialty or particularly large ships, such as the Australian Landing Helicopter Dock (LHD's), to offshore shipyards for both design and hull construction with final integration and fitting out done by Australian shipyards.

The Hybrid Model

In contrast to this integrated approach, a hybrid approach has recently been adopted by some nations to separate some components of the build and design. For example, the British MARS tanker program saw the "build contract…awarded to Daewoo Shipbuilding and Marine Engineering of South Korea, but the ships [will be] designed by a British company, BMT."[87] This occurred in part due to the lack of British firms bidding on the contract, but also because constructing the vessels' hull in Korea allowed for significant cost savings due to Daewoo's superior labour competitiveness.[88] A similar approach has been employed by the Dutch firm Daeman Schelde Naval Shipbuilding which has designed naval vessels, but built portions of the hulls in Eastern Europe to save money. However, it should be noted that the overseas shipyards are within the Daeman Schelde corporate structure.

In sum, separating the design and build contracts in Canada is relatively unique in comparison with the naval programs of other nations examined above.

As a means of mitigating the separate design and build contracts within the NSPS program, the Government signed an ancillary contract with Seaspan to engage the shipbuilder early in the design process so that they can provide input into the design phase from a builder's perspective and therefore avoid receiving a finished design that manifestly is more difficult or costly to build.

Design/Build and In-Service Support

The other major aspect in which the NSPS approach to building the JSS differs significantly from industry best practices is the separation of the shipbuilding contract from the in-service support arrangement. For example,

[86] National Audit Office, *Ministry of Defence: Carrier Strike* (11 July 2011), online: National Audit Office <http://www.nao.org.uk/publications/1012/carrier_strike.aspx>.

[87] Rt. Hon. Peter Luff, "Keynote Presentation," (Speech delivered at the Defence, Industries and Society Conference in London, 28-29 June 2012), <http://www.rusi.org/events/past/ref:E4F294A03A577A/info: public/infoID:E4FEC82B6D2C72/>.

[88] John Birkler, et al. *supra* note 77 at 59.

the UK's Type 45 destroyer program is based on a contracted level of availability from the shipbuilder. Whereas previously the government would acquire a ship and then continue to purchase spare parts and other services from industry to maintain it, under the current framework, the manufacturer is responsible for providing a specified level of equipment availability. The underlying motivation for taking this approach is to "incentivise industry to minimise the cost of support by, for example, developing more reliable equipments which are easier to maintain."[89] The Canadian government has adopted a similar approach to all of its major capital procurements since 2006 for the same reason. The acquisition of C-17s, C-130 Js, Chinook Helicopters and Army Logistics trucks were all announced as part of a combined procurement and in-service support contract with the original equipment manufacturer.[90] When the JSS was originally launched in 2006, the project was similarly designed to award both the procurement and in-service support contracts to the same company.[91] NSPS, however, is considering the in-service support contracts separately from the design and build contracts.

Design Capacity

The switch to separating the design and build contracts is notable because "Canadian designers have not been active on major government ship design work for over a decade."[92] As a result, the capacity for designing new ships is acknowledged to be low by defence industry groups. According to the Canadian Association of Defence and Security Industries (CADSI), there are five components of ship design: concept exploration; feasibility studies; functional design; detailed design; and in-service support. Only two Canadian shipyards, JD Irving Group and Fleetway Inc. combine either shipyard or prime contractor skills sets with design expertise. In part, this might be due to the government of Canada's broad application of conflict of interest provisions. These prevent contractors from working on both concept exploration and feasibility design phases for the government and subsequently becoming involved in the design and build or in-service support contracts if they are also involved in structuring the management of the project. Despite these limitations, CADSI's major study on shipbuilding recommended that the Government require design services for all aspects of the design, save the detailed design, be undertaken by Canadian companies.

Inventory of Projects

Seaspan operates two separate facilities in North Vancouver: Vancouver Drydock, which serves the wider marine industry, and Vancouver Shipyards, the facility that will be the primary worksite for Seaspan's NSPS shipbuilding efforts.

Since its inception in 1968, Vancouver Shipyards has worked on or constructed 170 vessels of all types. The construction of barges for Seaspan Marine sister companies has accounted for the majority of the shipyard's work, with the more than 100 barges built to date accounting for 60% of the yard's overall construction.

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[89] National Audit Office, *supra* note 85 at 24.

[90] National Defence and the Canadian Forces, *"Canada First" Defence Procurement – Tactical Airlift* (29 June 2006), online: <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?id=1970>; National Defence and the Canadian Forces, *"Canada First" Defence Procurement – Strategic Airlift* (29 June 2006), online: <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?id=1969>; National Defence and the Canadian Forces, *"Canada First" Defence Procurement – Medium-to-Heavy-Lift Helicopters* (28 June 2006), online: <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?id=1968>.

[91] National Defence and the Canadian Forces, *"Canada First" Defence Procurement – Joint Support Ship* (29 June 2006), online: <http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?id=1958>.

[92] CADSI Marine Studies Working Group, *supra* note 76 at iii.

Vancouver Shipyards has also been a prime contractor for the B.C. Ferries Corporation. This work includes constructing, refitting or repowering 24 ferries, and accounts for an additional 14% of the yard's work.

These ferries represent the largest vessels that the shipyard has constructed. In terms of vessel size, 6% of the yards overall output has been vessels which exceed 100m, with the longest vessel constructed to date being 120m in length. The largest vessel the researchers found in terms of tonnage was 6,422 tonnes. The Vancouver Shipyard's core experience is found in vessels that are between 50m-100m in length which account for 64% of the yard's experience to date. For the sake of comparison, the Berlin class is 173 meters long, and displaces 20,240 tonnes.

For illustrative purposes, the following table indicates how Seaspan's large vessel builds compare to the projected scale of the JSS build. At 24% longer and 215% more displacement, the JSS will be significantly larger than any other vessel previously constructed at a Seaspan facility.

Table 11-1: Seaspan Work

	Berlin	Large Ferries	Other Ferries	MV	Pacificat Class
Indicative Vessels of the class		Queen of Alberni Queen of Westminster (V class ferries)	Queen of Capilano Queen of Cumberland	MV Island Sky	Explorer Discovery Voyager
Length	173m	139m	96m	102m	122.5m
Tonnage	20,240	6,422	2,500	3,397	1,900

Note: While ferries account for the largest vessels built by Seaspan, not all ships of the class were built in Vancouver, as some ships of particular classes were built at Seaspan's Victoria yards.

Once work starts to ramp up for the non-combatant work package, the maintenance and repair work now shared between the North Vancouver and Esquimalt shipyards will shift to the Vancouver Drydock, to allow the Vancouver Shipyard to concentrate on NSPS shipbuilding.

Just fewer than 150 people currently work at the Drydock, but the number of employees will grow as the other facilities begin NSPS work. The Drydock currently performs maintenance and repair on four or five ships in the course of a month.[93]

Infrastructure and Workforce Improvements

[93] Simpson Scott, "Seaspan expects spillover from Coast Guard contract", *Vancouver Sun* (27 February 2012).

Having committed to continuing the long-standing Government of Canada policy on building federal ships in Canadian shipyards, the Government acknowledged that it would face major challenges in doing so. Without any naval ship construction projects since the completion of the Maritime Coastal Defence Vessels in 1999, the Canadian shipbuilding industry was in the midst of a downturn, relying on repair, maintenance and refits, in addition to commercial work. That the Canadian shipyards were not well positioned to deliver on the NSPS project was recognized, with this observation becoming part of the evaluation process under NSPS. First Marine International was enlisted to provide a benchmarking of the short listed shipyards to assess their respective capabilities on 159 elements of shipbuilding including:

- shipyard layout and material flow;
- steel plate cutting;
- sheet metal working;
- welding;
- vendor recruitment;
- strategic marketing planning;
- attitude to change and new technology;
- outfit manufacture;
- pre-erection activities;
- shipyard layout, design, engineering, operating systems;
- human resources;
- purchasing;
- marketing; and
- performance improvement.[94]

This evaluation compared the bidding shipyards to an international standard established by First Marine. This assessment, as well as the yard's plan for upgrading to reach that benchmark, accounted for 60% of the rated requirements used to evaluate bidders, with the assessment weighted 36% towards each yard's current state and 24% on its future plans for improvement. An additional 20% of the evaluation was attributed to the costs the Government of Canada would be required to pay to help the winning yards reach the target end state. Consequently, "Eighty (80) per cent of the total bid score [was] directly related to the shipyard's current state together with its plans and cost to Canada to fill any gaps to meet the target state defined by First Marine International."[95]

[94] Public Works and Government Services Canada, *Backgrounder: Achieving Best Value in Shipyard Selection*, (14 August 2012), online: Public Works and Government Services Canada <http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/ddi-bkgr-6-eng.html>.

[95] *Ibid*.

Figure 11-4: Planned Transformation of Seaspan

Current Facility | Facility Post Modernization

Source: Seaspan presentation to the Society of Naval Architects and Mechanical Engineers (SNAME) and the Canadian Institute of Marine Engineering (CIMarE) joint technical meeting.

Workforce

Ahead of the NSPS announcement, it was widely recognized that the largest challenge with the launch of this round of shipbuilding would be for the winning yards to “assemble and train a workforce.”[96] With an estimated 75 million person hours’ worth of labour require for the NSPS program, the demand for skilled labour is extremely high.[97] Furthermore, the type of skills required will also present a challenge. Seaspan’s Vancouver Shipyard has traditionally concentrated on commercial shipbuilding work, with its Victoria shipyard undertaking the bulk of its naval construction program. Nonetheless it is the Vancouver component of the operation that will undertake the initial phase of JSS construction, with Victoria playing only a post-construction role (see below). However, naval ship construction is significantly more technologically intensive than commercial ship construction.[98] Whereas the ratio of white to blue collar workers is roughly 1:6 for commercial shipbuilding, for naval programs, it is roughly 1:1.7. This discrepancy is primarily due to more significant requirements for engineering and professional support with naval programs, although these differences are less pronounced for auxiliary ships than warships.[99]

Thus, Seaspan faces three types of workforce challenges:

[96] CADSI Marine Studies Working Group, *supra* note 76 at iii.

[97] Minister of Public Works and Government Services and Minister for the Status of Women, *Minister’s Statement on National Shipbuilding Procurement Strategy* (October 19, 2011), online: Public Works and Government Services Canada <http://www.tpsgc-pwgsc.gc.ca/medias-media/ds/2011-10-19-00-eng.html>.

[98] Mark V. Arena, et al. *supra note 35*

[99] John Birkler, et al. *supra* note 77.

1. increasing the aggregate number of workers;
2. adjusting the skill mix amongst them to reorient away from commercial shipbuilding to naval shipbuilding; and
3. increasing the capacity of its workforce.

On the first front, Seaspan will face challenges in increasing the size of the workforce. As recently as November 2009, the company was downsizing its labour component because of the economic downturn, including reductions to its shipyard workforce specifically.[100] Thus as of April 25, 2012, Seaspan's shipyard in North Vancouver had a total workforce of 338. The company predicts that the workforce will increase to approximately 500 workers by late 2012 or early 2013 as the company begins to lay down the hull for the first four fisheries research and oceanographic vessels that will be constructed. The bulk of this expansion will be comprised of skill positions including welders, electricians, shipwrights and office staff. The subset workforce is expected to expand again to 1,000 for the construction of the JSS and Polar icebreaker. However, these numbers appear to be rough approximations as the Seaspan CEO recently stated that they might increase to roughly 1,200 by 2016.[101] In contrast, the Victoria shipyard currently stands at 800 employees and will only expand to a total of 1,000. A total of 1,222 workers are currently employed at the Esquimalt Graving Dock, including those working for Public Works and Government Services Canada and other companies.

Adjusting the skill mix of Seaspan's workforce may take some time as the NSPS program is placing increasing demands on highly skilled workers. "The strongest shipbuilding demand is expected in trades such as welding, metal fabricating, plumbing, pipefitting, mechanics and electricians."[102] To that end, new training arrangements are being completed with the British Columbia Institute of Technology (BCIT) to ramp up programs to fill the projected skill gaps. BCIT will create a "centre of excellence" for shipbuilding with Victoria's Camosun College to add specific shipbuilding content to existing management and vocational programs. This initiative would educate welders about how to safely work in confined spaces, such as the belly of a ship.[103] Significant improvements to the training curriculum are required because several aspects of the shipbuilding occupations, including programs for shipwrights and marine fitters, have not been offered in British Columbia in some time.[104] Robotics and computers have recently become more integrated in the shipbuilding program, which may also increase the demand for trained technicians and technologists.[105]

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[100] Rajesh Joshi, "Washington Marine Group axes staff", Lloyds *List* (20 November 2009).

[101] Gordon Hamilton, "Seaspan launches $200-million shipyard upgrade," *Vancouver Sun* (20 October 2012) online: <http://www.leaderpost.com/story_print.html?id=7421454&sponsor=>.

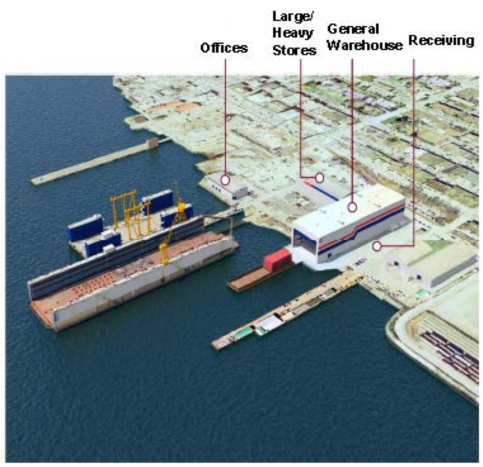
[102] Carla Wilson, "10M from BC will aid shipbuilding," *Times Colonist* (6 December 2011).

[103] Christopher Pollon, "Seaspan Whipped into Ship Shape," *BC Business* (ND) online: <http://www.bcbusinessonline.ca/transportation/seaspan-whipped-ship-shape>.

[104] Carla Wilson, *supra* note 102.

[105] Christopher Pollon, *supra* note 103.

Table 11-2: Vancouver Dry dock improvements



Finally, Seaspan is also attempting to increase the capacity resident in its workforce by bringing in more experienced workers. As a result, the marine industry unions are seeking to bring in experienced journeyman for trades related to marine work with the intent of upgrading their skills as a means of boosting their initial workforce. As a result, Seaspan believes that it will not need to source the bulk of its trades people from overseas. Nonetheless, it will still seek foreign workers for specific occupations such as engineers, project managers and naval architects.[106] The workforce, while potentially experienced generally, will have less direct shipbuilding experience than would be desirable; in the words of one union representative, "You're building from the floor up. There is nothing there."[107]

Labour Relations

Seaspan has just concluded labour agreements with its unions, the majority of which bargain under a poly party union arrangement which is somewhat unique to British Columbia. In support of Seaspan's NSPS bid, the Poly Party Unions committed to cooperatively source manpower for the shipyard from across Canada and from Western Canada in particular. The unions equally committed to participating in various training and apprenticeship programs to ensure that the "correct skill sets and competencies" were available to the yard to meet its build requirements. The unions further committed to ensuring labour peace and to provide labour stability for the duration of the NSPS program including no strike/no lockout provisions in accordance with their collective agreements. As of this report, Seaspan is in negotiations for a new collective bargaining agreement with one of its unions, COPE (Canadian Office and Professional Employees - local 378), which is under a strike mandate but presently honouring its previous agreement~~.~~

Infrastructure

In addition to making a substantial workforce upgrade, Seaspan will also have to significantly increase its shipyard infrastructure. This will be based on a combination of the requirements set by the NSPS Request for Proposal, as well as Seaspan's post-NSPS plan for long-term industrial work. For the latter consideration, Seaspan believes that their future as a commercial shipbuilder rests on being "a niche player, specifically in that mid-sized market—the coast guard cutter, icebreaker market."[108] To affect this long-term work, their goal is to have the Government of Canada with its NSPS contracts, serve as an "anchor tenant" for the shipyard. In doing so, the federal government will help share the costs of Seaspan's infrastructure overhead in a manner that it hopes will allow the shipyard to be commercially competitive.

In February 2012, Seaspan signed its umbrella agreement with the Government. On the strength of this guarantee, Seaspan has begun to move ahead on a wide range of upgrades. Although accounts vary slightly in the details, upgrades are believed to represent roughly $200 million worth of changes to their facilities.

[106] Gordon Hamilton, *supra* note 101.

[107] Darah Hansen & Brian Morton, "Deal with federal government pulls B.C. shipyard industry out of long slump," *Vancouver Sun* (11 October 2011).

[108] Christopher Pollon, *supra* note 103.

At the Vancouver Shipyard, infrastructure modifications will entail adding four specialized buildings and installing new equipment in several others. New profile cutting, sub-assembly and panel lines will be added by constructing a new fabrication and panel line building, incorporating a robotic profile line and automated flat panel line. A new curve block assembly building will also be built, incorporating dedicated plate forming equipment, two 40 tonne cranes, specialized jigs and fixtures for complex curved blocks and specialized service kiosks. The new blast and paint building to support new construction and repairs will separate the blast and paint operations. A new pre-outfitting building will be constructed with two 25 tonne cranes and one 10 tonne crane. Furthermore, the flat block assembly building will be reconfigured to accommodate new equipment and services including dedicated flat subassembly and major subassembly stations, modular rolling jigs for flat block assembly, service kiosks and manifolds, and a 300 tonne gantry crane. Furthermore, the existing facility where plate and profile forming occurs will be adding plate rolls, a 400 tonne frame bender, a 900 tonne press brake, a 9 tonne crane, and an electric carriage to deliver parts directly to the flat and curved assembly buildings.

Both the grand block assembly and erection areas will also be enhanced. The grand block assembly building will feature cold outfit systems, and be capable of joining multiple hull blocks into grand blocks. It will also feature two 60 tonne cranes, one 20 tonne crane, and service kiosks. The ship erection site will be reinforced to withstand ship loading, provide temporary environmental shelter, and install a self-propelled modular transporter to position grand blocks into their build positions and transfer the vessel to the launch dock.

A new central warehouse will also be added to increase onsite storage of high use items and institute a better tracking and control system. Furthermore, existing facilities will be converted into additional warehousing to accommodate high density racking, storage for heavy items such as main engines, with the aid of a 40 tonne gantry crane (at the Vancouver dry dock facility), as well as additional climate controlled storage.

Figure 11-5: Planned Transformation of Seaspan

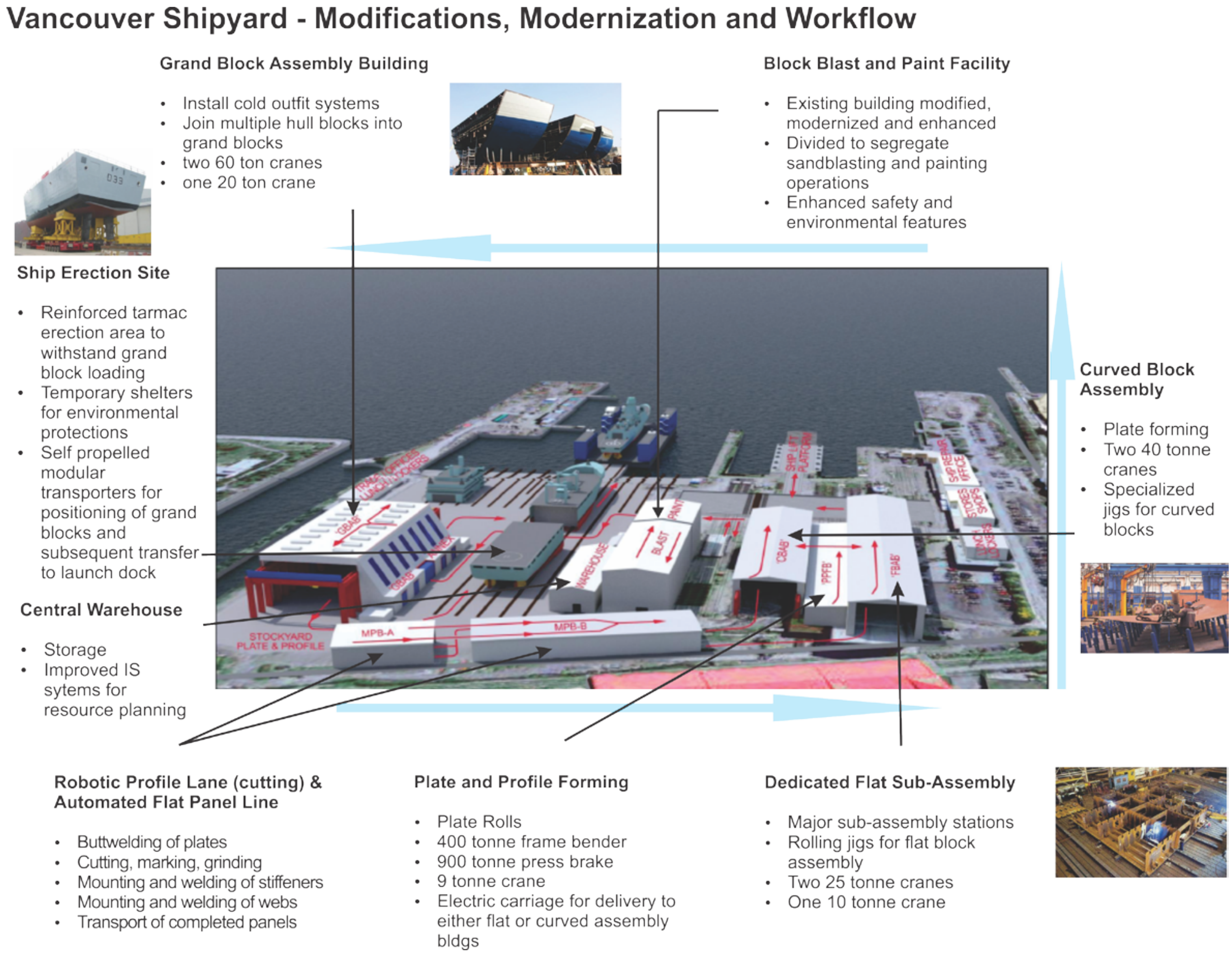
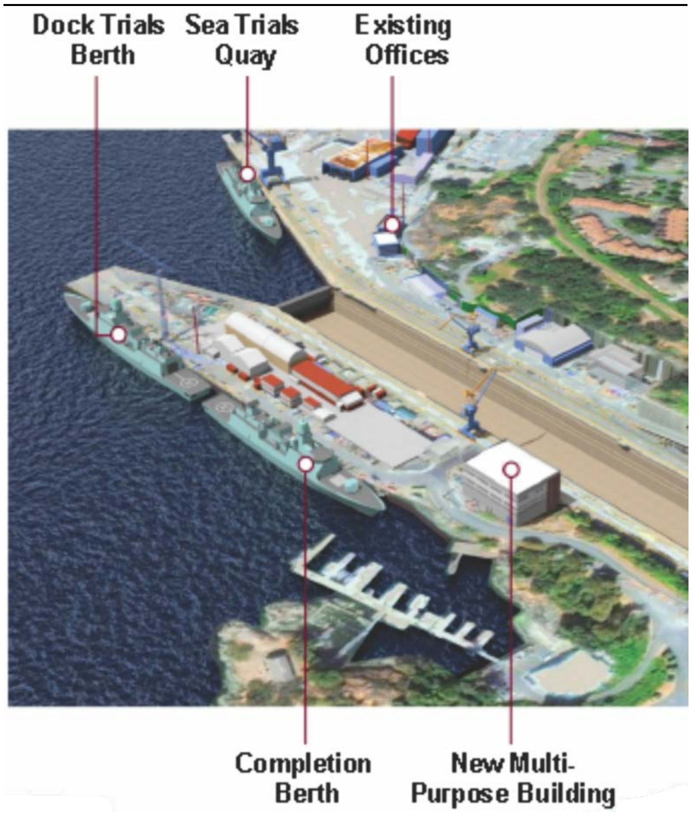


Figure 11-6: Forecast Victoria Shipyard Improvements



While major construction will be completed at the Vancouver Shipyard, once launched, NSPS vessels will be towed to the Victoria shipyard for completion. This will see the final zone outfit system completion, system integration, set-to-work activities, dock and sea trials and in-service support activities take place in Victoria. To facilitate these initiatives, the Victoria Shipyard will require a new multipurpose building that houses a secure warehouse, trade shops and tool cribs, safety and first aid, and additional office space. Overall, Victoria Shipyards will see refurbishings between $15–30 million. Construction on these modifications was slated to begin in October 2012 and be completed by 2015. This investment represents the privately held company's own financial investment, as required under the provisions of the NSPS.[109]

It was also recently announced that $101 million in funding would be provided over five years to improve the graving dock.[110]

As part of this overall reorganization, Seaspan has entered into a technology support agreement with the Korean company STX Offshore and Shipbuilding Company Ltd. The company, staffed primarily by former Daewoo shipbuilders, is providing Seaspan with its knowledge of one of the world's most productive ship yards to help them upgrade their facilities. The arrangement with STX will initially focus on optimizing shop layouts, material flow, and production methods and processes; in essence, the facilities upgrade will be designed by the STX firm.[111]

[109] Christopher Pollon, *supra* note 103.

[110] Government of Canada, *Harper Government Announces Investment in Esquimalt Graving Dock* (Esquimalt: June 27, 2012), online: Canada News Centre, <http://news.gc.ca/web/article-eng.do?nid=682889

[111] R. Bruce Striegler, "Seaspan gears up for NSPS construction", *Canadian Sailings* (14 May 2012).

Table 11-3: Government Ships Built by Seaspan

Hull #	O.N.	Original Name	Original Owner	Vessel Type	Year built	Vessel Length (metres)
142	821039	Osprey 2000	B.C. Ministry of Highways	Ferry	2000	76.50 m
137	821047	Pacificat Voyager	B.C. Ferry Corporation	High Speed Ferry	1998	122.7 m
136	821018	Pacificat Discovery	B.C. Ferry Corporation	High Speed Ferry	1998	122.7 m
135	820007	Pacificat Explorer	B.C. Ferry Corporation	High Speed Ferry	1997	122.7 m
130	322953	Queen of New Westminster	B.C. Ferry Corporation	Ferry	1991	120.24 m
127	815254	Queen of Cumberland	B.C. Ferry Corporation	Ferry	1992	95.98 m
126	812656	Queen of Capilano	B.C. Ferry Corporation	Ferry	1991	95.98 m
125	812626	Needles	B.C. Dept. of Highways	Ferry	1990	49.99 m
102	801691	Quinsam	B.C. Dept. of Highways	Ferry	1982	86.84 m
99	368854	Queen of the North	B.C. Ferry Corporation	Ferry	1981	125.0 m
79	318636	Queen of Vancouver (Repowering)	B.C. Ferry Corporation	Ferry	1978	120.24 m
78	314040	Queen of Victoria (Repowering)	B.C. Ferry Corporation	Ferry	1978	nlic
71	None	Unnamed	B.C. Dept. of Highways	Tubular Float	1977	27.43 m
70	383249	Quinitsa	B.C. Dept. of Highways	Ferry	1977	74.52 m
62	370066	Queen of Alberni	B.C. Ferry Corporation	Ferry	1976	133.50 m
49	347780	Kahloke	B.C. Dept. of Highways	Ferry	1973	54.71 m
39	347141	L. Pacifica	Dept. of the Environment	Research Barge	1973	26.52 m
34	319730	Howe Sound Queen	B.C. Ferry Corporation	Ferry	1972	63.09 m
30	345965	Denman Queen/Klitsa	B.C. Dept. of Highways	Ferry	1972	45.06 m
29	345961	Klatawa	B.C. Dept. of Highways	Ferry	1972	47.46 m
28	345956	Kulleet	B.C. Dept. of Highways	Ferry	1972	47.46 m
27	331716	Merv Hardie (Modifications)	Min. of North & Indian Affairs	Ferry	1972	40.96 m
25	318636	Queen of Vancouver	B.C. Ferry Corporation	Ferry	1972	120.24 m
24	331716	Merv hardie	Min. of North. & Indian Affairs	Ferry	1971	40.96 m
10	344744	Prince Rupert Airport Ferry	City of Prince Rupert	Ferry	1970	34.29 m

Table 11-4: Commercial Ships Built by Seaspan

Hull #	O.N.	Original Name	Original Owner	Vessel Type	Year built	Vessel Length (metres)
171	833507	P.B. 34	Marine Petrobulk	Tank Barge	2009	82.79 m
170	833151	Seaspan 827	Seaspan International	Tank Barge	2008	70.37 m
169	832118	Smit MSG 2802	Smit Marine Canada	Barge	2007	58.50 m
167	832720	Island Sky	B.C. Ferry Services	Ferry	2008	95.72 m
166	828618	Smit MSG 2801	Smit Marine Canada	Barge	2006	58.51 m

165	827776	Seaspan 534	Seaspan International	Barge	2005	58.52 m
164	827728	Seaspan 533	Seaspan International	Barge	2005	58.52 m
163	827539	Seaspan 532	Seaspan International	Barge	2005	58.52 m
162	827283	Seaspan 531	Seaspan International	Barge	2005	58.52 m
161	826798	Seaspan 642	Seaspan International	Barge	2004	74.91 m
160	826370	Seaspan 530	Seaspan International	Barge	2004	58.52 m
159	826369	Seaspan 529	Seaspan International	Barge	2004	58.52 m
158	826091	Seaspan 528	Seaspan International	Barge	2004	58.52 m
157	825863	Seaspan 527	Seaspan International	Barge	2004	58.52 m
156	825614	Seaspan 526	Seaspan International	Barge	2003	58.52 m
155	825381	Seaspan 525	Seaspan International	Barge	2003	58.52 m
154	825380	Seaspan 524	Seaspan International	Barge	2003	58.52 m
153	822114	P.B. 32	Marine Petrobulk	Tank Barge	2003	79.68 m
149	823140	GMS 620	Gemini Marine Svc.	Barge	2001	58.38 m
148	822731	Seaspan 641	Seaspan International	Barge	2001	65.55 m
147	825259	Seaspan 523	Seaspan International	Barge	2003	58.52 m
146	822730	Seaspan 510	Seaspan International	Barge	2001	58.52 m
144	822609	Seaspan 509	Seaspan International	Barge	2000	58.52 m
143	822588	Seaspan 508	Seaspan International	Barge	2000	58.52 m
141	820069	Seaspan 553	Seaspan International	Barge	1998	62.04 m
140	820068	Seaspan 552	Seaspan International	Barge	1998	62.04 m
139	820067	Seaspan 551	Seaspan International	Barge	1998	62.04 m
138	820066	Seaspan 550	Seaspan International	Barge	1998	62.04 m
134	818048	ITB Pioneer	Island Tug & Barge	Tank Barge	1994	60.96 m
133	816602	Seaspan Falcon	Seaspan International	Tug	1993	22.36 m
132	816601	Seaspan Hawk	Seaspan International	Tug	1993	22.36 m
131	Foreign	Seaspan 271	Seaspan International	Barge	1992	
129	814185	Seaspan 507	Seaspan International	Barge	1990	60.96 m
128	814153	Seaspan 506	Seaspan International	Barge	1990	60.96 m
124	812817	Seaspan 505	Seaspan International	Barge	1989	60.96 m
123	812795	Seaspan 504	Seaspan International	Barge	1989	60.96 m
122	812762	Seaspan 503	Seaspan International	Barge	1989	60.96 m
121	812761	Seaspan 502	Seaspan International	Barge	1989	60.96 m
120	810112	Seaspan 501	Seaspan International	Barge	1989	60.96 m
119	810111	Seaspan 500	Seaspan International	Barge	1989	60.96 m
118	811187	Seaspan 499	Seaspan International	Barge	1988	60.96 m
116	809691	Seaspan 498	Seaspan International	Barge	1987	60.96 m

115	331288	Evco 91 (lengthened)	Ocean Construction Supplies	Barge	1986	82.91 m
113	805628	Seaspan 497	Seaspan International	Barge	1985	60.96 m
112	805627	Seaspan 496	Seaspan International	Barge	1985	60.96 m
111	805626	Seaspan 495	Seaspan International	Barge	1985	60.96 m
110	804843	Seaspan 494	Seaspan International	Barge	1985	60.96 m
109	804842	Seaspan 493	Seaspan International	Barge	1985	60.96 m
108	804841	Seaspan 492	Seaspan International	Barge	1984	60.96 m
107	804174	Seaspan Discovery	Seaspan International	Tug	1984	32.71 m
106	803537	Miscaroo	Beaudril (Gulf Oil Canada)	AHTS	1983	79.25 m
105	801807	Arctic Ublureak	Arctic Transportation	AHTS	1982	42.37 m
104	Export	Western Polaris	Western Geophysical Co.	Research Vessel	1982	44.60 m
103	Export	Western Aleutian	Western Geophysical Co.	Research Vessel	1982	44.60 m
101	Export	Heron	Mar Fishing	Trawler	1982	39.01 m
100	Export	Ibis	Mar Fishing	Trawler	1982	39.01 m
98	None	Unnamed	Crown Zellerbach	Tubular Floats	1980	
97	348609	Ocean King	Jake Egeland Fish Co.	Trawler	1980	28.19 m
96	393934	Jennifer Gayle	Banks Marine	Troller	1980	16.25 m
95	800112	Seaspan 491	Seaspan International	Barge	1981	60.96 m
94	800111	Seaspan 490	Seaspan International	Barge	1981	60.96 m
93	395920	Seaspan 489	Seaspan International	Barge	1980	60.96 m
92	395919	Seaspan 488	Seaspan International	Barge	1980	60.96 m
91	369689	Swiftsure II	Swiftsure Towing	Tug	1979	25.09 m
90	Export	Satro 25	Astro Maritima	Offshore Supply	1980	54.86 m
89	393357	Sea Crest	D. Knotts	Trawler	1980	23.84 m
88	395390	Seaspan Rigger	Seaspan International	Barge	1980	120.79 m
87	392782	Seaspan 487	Seaspan International	Barge	1979	60.96 m
86	392234	Seaspan 486	Seaspan International	Barge	1979	60.96 m
85	392181	Seaspan 485	Seaspan International	Barge	1979	60.96 m
84	331830	Seaspan 191	Seaspan International	Barge	1979	72.05 m
83	392947	Free Enterprise No. 1	Phil Burgess	Trawler	1979	23.65 m
82	391368	Downie No. 2	Downie Street Sawmills Ltd.	Ferry	1978	27.43 m
81	Export	Ultra Processor No. 1	Norlympia Seafoods	Factory Barge	1979	62.18 m
80	189270	Seaspan 621	Seaspan International	Barge	1979	71.63 m
77	391362	Seaspan 931	Seaspan International	Barge	1978	103.33 m
76	383466	Seaspan 484	Seaspan International	Barge	1978	60.96 m
75	383465	Seaspan 483	Seaspan International	Barge	1978	60.96 m
74	383464	Seaspan 482	Seaspan International	Barge	1978	60.96 m

69	371179	Seaspan 193	Seaspan International	Barge	1976	72.02 m
68	371166	Seaspan 192	Seaspan International	Barge	1976	72.02 m
67	Export	Boqueron	Eximbal/Guatemala	Barge	1976	64.01 m
66	Export	Setal	Eximbal/Guatemala	Barge	1976	64.01 m
65	Export	Seaspan Royal	Seaspan International	Tug	1976	42.67 m
64	370250	Seaspan Cutlass	Seaspan International	Tug	1975	23.99 m
63	370217	Seaspan Corsair	Seaspan International	Tug	1975	23.99 m
60	348027	NT 1804	Northern Transportation	Tank Barge	1974	64.01 m
59	348026	NT 1803	Northern Transportation	Tank Barge	1974	64.01 m
58	348875	S.N.No. 3	Egmont Towing & Salvage	Barge	1974	71.63 m
55	329223	Gulf Hathi	Gulf of Georgia Towing	Barge	1974	94.79 m
54	329216	Gulf Horpe	Gulf of Georgia Towing	Barge	1974	94.79 m
53	369522	Seaspan Cavalier	Seaspan International	Tug	1975	23.99 m
52	368748	Sea Mark XV	W.S. Brodie & Sons	Log Bundling Pontoon	1974	12.19 m
51	348453	Evco 71	Ocean Construction Supplies	Barge	1973	74.46 m
50	348431	Evco 70	Ocean Construction Supplies	Barge	1973	74.46 m
48	369068	Seaspan Commodore	Seaspan International	Tug	1974	40.38 m
47	348499	Seaspan Crusader	Seaspan International	Tug	1974	23.99 m
46	347534	NT 1520	Northern Transp.	Tank Barge	1973	76.23 m
45	347533	NT 1520	Northern Transp.	Tank Barge	1973	76.23 m
44	347532	NT 1519	Northern Transp.	Tank Barge	1973	76.23 m
43	347531	NT 1518	Northern Transp.	Tank Barge	1973	76.23 m
42	346530	NT 1517	Northern Transp.	Tank Barge	1973	76.23 m
41	346529	NT 1516	Northern Transp.	Tank Barge	1973	76.23 m
40	346528	NT 1515	Northern Transp.	Tank Barge	1973	76.23 m
38	330833	Bute No. 6 (lengthened)	Bute Towing Co.	Barge	1973	63.40 m
37	331169	Peace Prince	Seaspan International	Tug	1973	11.06 m
36	330607	Peace Piper	Seaspan International	Tug	1973	9.94 m
35	330401	Seaspan 822	Seaspan International	Tank Barge	1972	73.15 m
33	347011	G. of G. 382	Gulf of Georgia Towing	Barge	1972	54.86 m
32	346705	G. of G. 381	Gulf of Georgia Towing	Barge	1972	54.86 m
31	346690	G. of G. 380	Gulf of Georgia Towing	Barge	1972	54.86 m
26	345722	V.P.D. No. 32	Vanc. Pile Driving Co.	Barge	1971	15.24 m
23	345708	Seaspan 481	Seaspan International	Barge	1971	60.96 m
22	345649	Seaspan 480	Seaspan International	Barge	1971	60.96 m
21	345188	Transporter 5	North Arm Transp.	Barge	1971	58.52 m
20	198820	G.C.26	North West Dredging	Barge	1969	

19	345120	S.N. No. 2	Shields Navigation Ltd.	Tank Barge	1970	51.69 m
18	344688	G. of G. 500	Gulf of Georgia Towing	Barge	1970	63.40 m
17	323296	Rivtow 104	Rivtow Straits Ltd.	Barge	1970	53.34 m
16	319418	V.T.No. 150	Vanc. Tug Boat Co.	Barge	1970	83.82 m
15	345249	Hecate Straits	Rivtow Straits Ltd.	Tug	1971	21.12 m
14	331888	V.T.No. 197	Vanc. Tug Boat Co.	Barge	1969	55.47 m
12	331868	V.T.No. 196	Vanc. Tug Boat Co.	Barge	1969	55.47 m
11	331305	V.P.D.No. 35	Vanc. Pile Driving Co.	Dump Scow	1969	49.99 m
9	345112	La Garde	Vanc. Tug Boat Co.	Tug	1970	23.56 m
8	331830	V.T.No. 156	Vanc. Tug Boat Co.	Barge	1969	72.05 m
7	331264	Pacific Barge 101	Vanc. Tug Boat Co.	Barge	1969	73.15 m
6	330833	Bute No. 6	Bute Towing Co.	Tank Barge	1969	63.40 m
5	330890	N.T.1009	Northern Transportation	River Barge	1969	60.96 m
4	330754	V.T.No. 189	Vanc. Tug Boat Co.	Barge	1968	54.86 m
3	330421	V.T.No. 188	Vanc. Tug Boat Co.	Barge	1968	54.86 m
2	330387	V.T.No. 187	Vanc. Tug Boat Co.	Barge	1968	54.86 m
1	330346	V.T.No. 186	Vanc. Tug Boat Co.	Barge	1968	54.86 m